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Some silvicultural ecosystems in the Yukon

Walter Stanek and Laszlo Orloci

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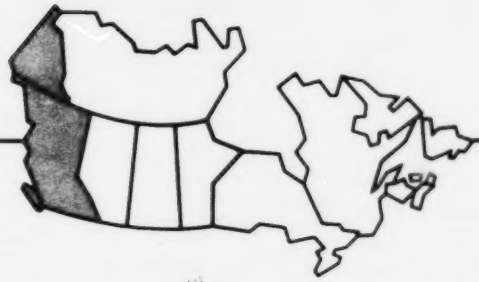

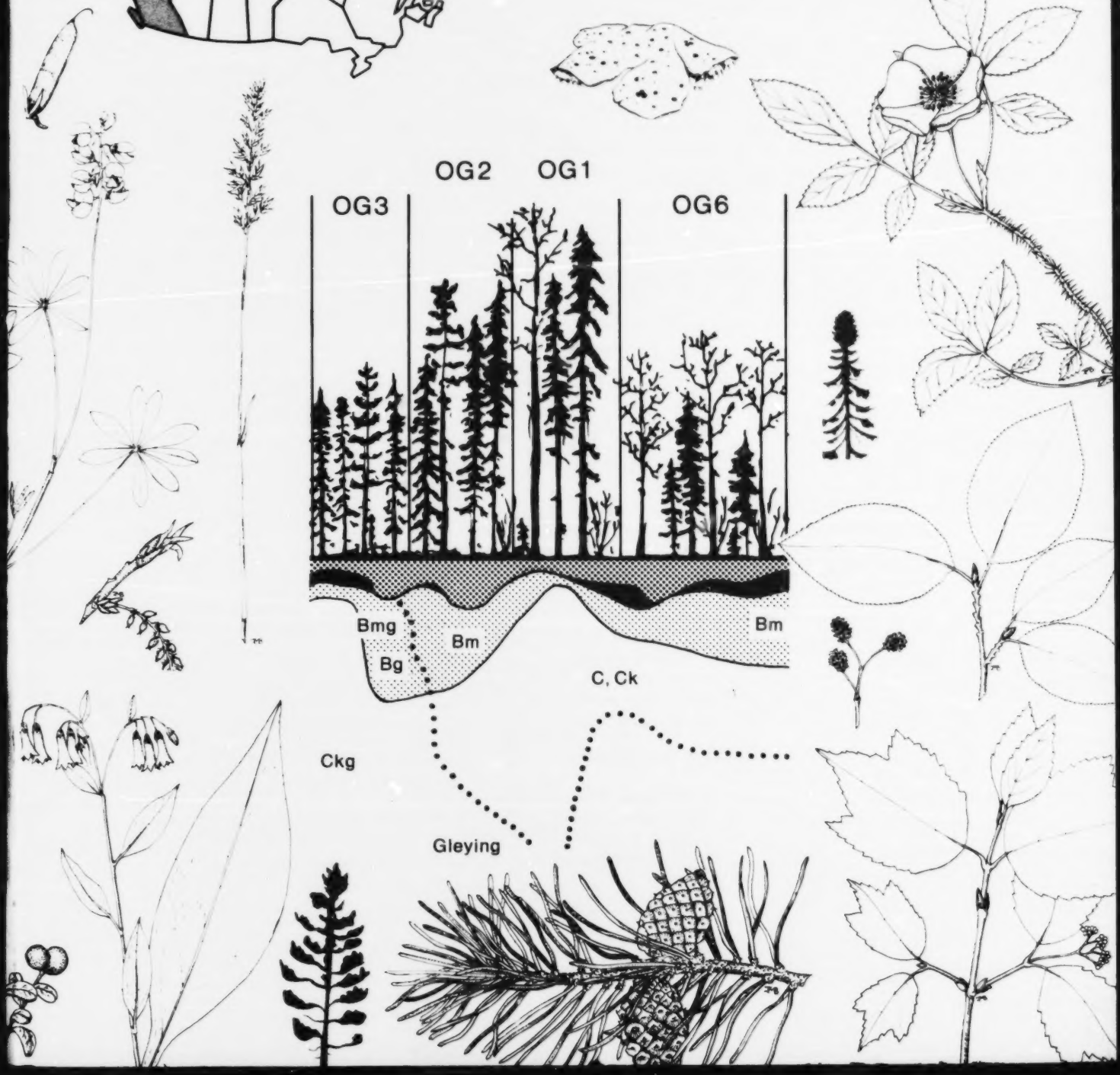

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Some silvicultural ecosystems in the Yukon

by

Walter Stanek and László Orlóci
Illustrations by Jane M. Bowles

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NOTE

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Abstract

This guide provides a key to the differentiation of eight silvicultural ecosystems, here called operational groups, contained within forest complexes in the southern Yukon. The operational groups are intended to aid the forester in designing silvicultural measures within the scope of a forest management plan, and are suitable for use in combination with or as the basis of forest inventories.

The key to operational groups is based on 21 forest types, including wetland shrub types, identified by cluster analyses of vegetation data and by a mathematical method called ordination. To facilitate practical applications of the key, merchantability of the forest trees, incidence of permafrost, and site index were introduced into the scheme in addition to lists of characteristic plant species. To determine the operational group, a guide user must assign the forest stand in question to a tree species (spruce or tamarack, lodgepole pine, poplar or aspen) based on cover. Characteristic plant species combinations are also listed. The user then decides whether or not the trees are or will become merchantable in size, (a minimum height of 5 m at the base age of 50 years) and whether or not there is permafrost in the soil. In stands composed mainly of spruce, further divisions assign the stands according to the site index. The key is followed by interpretations to operational groups. They contain suggestions of a silvicultural nature.

To aid in determining the operational group, one or several examples of forest types per operational group are presented. These examples contain stand cross sections, soil horizon views, and information on forest and plant covers, permafrost, soil types, soil texture, soil pH, and moisture regime. The site index curves for white spruce and lodgepole pine indicate the growth potential of trees on sites of different quality.

In the Appendices are tables for field determination of moisture regimes of mineral soils with and without permafrost, as well as diagrams of forest types in relation to selected environmental variables, and illustrations of plants used in the key.

Résumé

Ce guide fournit une méthode permettant de différencier huit écosystèmes sylvicoles (appelés ici groupes opérationnels) dans les zones forestières du sud su Yukon. La répartition en groupes opérationnels vise à aider les forestiers à établir les mesures réclamées par leur plan de gestion forestière; les groupes peuvent entrer en combinaison avec les inventaires forestiers ou leur servir de support.

Les groupes opérationnels sont formés à partir de 21 types de végétation forestière, y compris les arbustes des marécages; ces types résultent d'analyses d'ensemble portant sur les données fournies par la végétation ou d'une méthode mathématique appelée ordination. Pour faciliter l'application pratique de la méthode proposée dans le guide, on a incorporé au schéma général, en plus des listes d'espèces végétales caractéristiques, la commercialisation des arbres, la présence éventuelle du pergélisol et l'indice de station. Pour former un groupe opérationnel, l'utilisateur du guide doit d'abord déterminer quelle espèce d'arbre entre dans le peuplement concerné (épinette, mélèze, pin lodgepole, peuplier ou tremble). Le guide donne aussi les combinaisons caractéristiques des espèces de plantes. L'utilisateur est appelé à établir si les arbres ont ou auront une taille suffisante pour pouvoir être commercialisés (hauteur minimum de 5 m à 50 ans) et si le pergélisol affecte tel au tel endroit. Dans les peuplements composés surtout d'épinette on subdivise à nouveau selon l'indice de station. L'exposé de la méthode est suivi de développements ayant trait aux groupes opérationnels et contenant des suggestions en matière de sylviculture.

Pour faciliter le travail, le guide donne un ou plusieurs exemples de types de peuplement par groupe opérationnel. Ces exemples sont illustrés de peuplements vus en coupe, de coupes géologiques et de renseignements sur la couverture des arbres, des plantes, le pergélisol, les types de sol, la texture et le pH des sols, le régime hygrométrique. L'indice de station de l'épinette blanche et du pin lodgepole renseigne sur le potentiel de croissance des arbres sur des sols de différente qualité.

Les appendices contiennent des tableaux permettant de déterminer sur place le régime hygrométrique des sols, avec ou sans pergélisol, des diagrammes de types de forêt établis en fonction de certaines variables environnementales et des illustrations de plantes ayant servi dans l'exposé de la méthode.

Introduction

This guide relies on data from 323 plots randomly located in a stratified design along the Alaska Highway between Watson Lake, Yukon Territory, and the Alaska border (Figure 1), a distance of close to 900 km. These plots were originally established in 1978. Initial reports were presented by Orlóci and Stanek (1979), Stanek (1980), and Lausi and Nimis (1985). Subsequently, data on soil and tree growth were collected and incorporated. In this guide, only those vegetation types containing tree species are included. The guide covers an area in which the regional ecology (Eyre 1963; Riley and Young 1966; Rowe 1972; Fremlin 1973; Oswald and Senyk 1977) has been relatively well known for some time, but forest ecosystems and operational groupings have scarcely been investigated (Oswald and Brown 1986; Davies et al. 1983).

This guide is intended to provide a logical scheme for classifying forest stands in the southern Yukon into operational groups. For practical purposes, the operational groups are the forest stands that the operational forester deals with during the planning, harvesting and regeneration, release and stand-tending stages of forest management (Jones et al. 1983). The guide contains much of the information needed to efficiently plan stand treatments and offers the practitioner a simple key to identify the operational groups.

The interpretations of the operational groups are intended to aid silvicultural decision-making in the field. With a few exceptions (communities with alpine fir, *Abies lasiocarpa*, not occurring along the surveyed route) the guide has wide application.

The individual operational groups are the result of groupings of relevant vegetation types, subsequently called forest types, according to similar ecosystematic characteristics such as plant species, tree growth potential, and soil conditions. One or several forest type descriptions for each operational group are given as examples.

The site index curves are for estimating the tree growth potential, which is important in assessing the quality of a site. The height-age relationship is also needed to characterize the operational groups. For those who prefer to rely primarily on vegetation for classification purposes, the plants listed in the key to operational groups as well as in the forest type examples are dominant, characteristic indicators, and are suitable for deriving the operational groups.

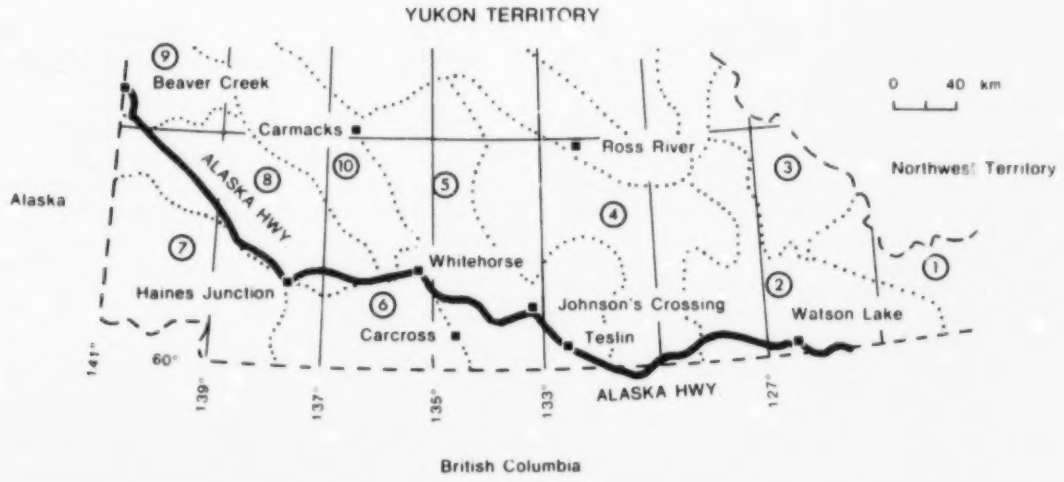

Figure 1. Map of southern Yukon Territory showing the Alaska Highway in relation to other major roads, towns and boundaries (dotted lines) of Oswald and Senyk's (1977) ecoregions traversed by the survey: 2 (Liard River), 4 (Pelly Mountains), 5 (Lake Laberge), 8 (Ruby Range), 9 (Wellesley Lake).

To simplify the guide, only the results of the statistical evaluation of vegetation and environmental factors using cluster analysis or ordination are included. The scatter diagrams of forest types and environmental factors (Figure B1 to B5) allow comparisons between the forest types, and support results presented in the key.

Key to operational groups

The analyses of relationships of forest types revealed that environmental gradients strongly influence tree growth. These environmental gradients are predictable based on the forest type, and the types may serve as an operational basis of forest utilization. However, the forest landscape is commonly complex and several vegetation types may occur in a relatively small area. For that reason, the forest types were classed into operational groups (Figure 2) which can be identified with the key (Figure 3). The interpretations of to the operational groups are intended as an operational aid.

To use the key, identify the main forest tree species (spruce or tamarack, lodgepole pine, poplar or aspen) and, for confirmation, one or more of the understory plant species listed (Figure 3). Next, estimate the merchantability of the trees. In the Yukon, merchantable trees are those trees having a top diameter inside bark of 10 cm, a diameter at breast height inside bark of 18 cm, and a stump height above root flare of 30 cm (personal communication, N. Denmark, Regional Manager, Forest Resources, Department of Indian Affairs and Northern Development, Whitehorse). Nonmerchantable is used in the sense of unproductive (Bonnor 1982), incapable of producing a merchantable stand within a reasonable length of time; specifically, a stand is nonmerchantable if it has a site index of less than 5 m at the base age of 50 years. In the third step, identify sites with permafrost less than 1 m deep. In most cases the ice will be located the interface of organic and mineral soil. Brown and Kupsch (1974) defined permafrost and seasonal frost. To facilitate differentiation between the two in the field, Stanek (1980) defined permafrost as a ground that remained frozen into late September in a layer which

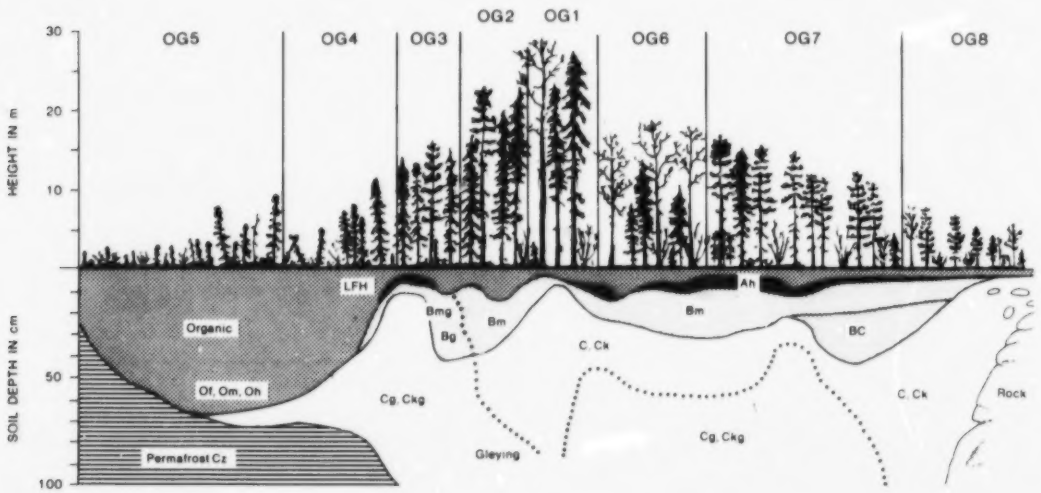

Figure 2. Schematic landscape cross section showing the approximate position of eight operational groups (OGs). Tree heights in metres are at 100 years of age (SI/100); soil depth is in centimeters. The soil profile is a composite of the most common soils in the surveyed area. The soil moisture decreases from left to right. Gleying occurs to the left of the dotted line. (See Glossary for definitions of terms and abbreviations).

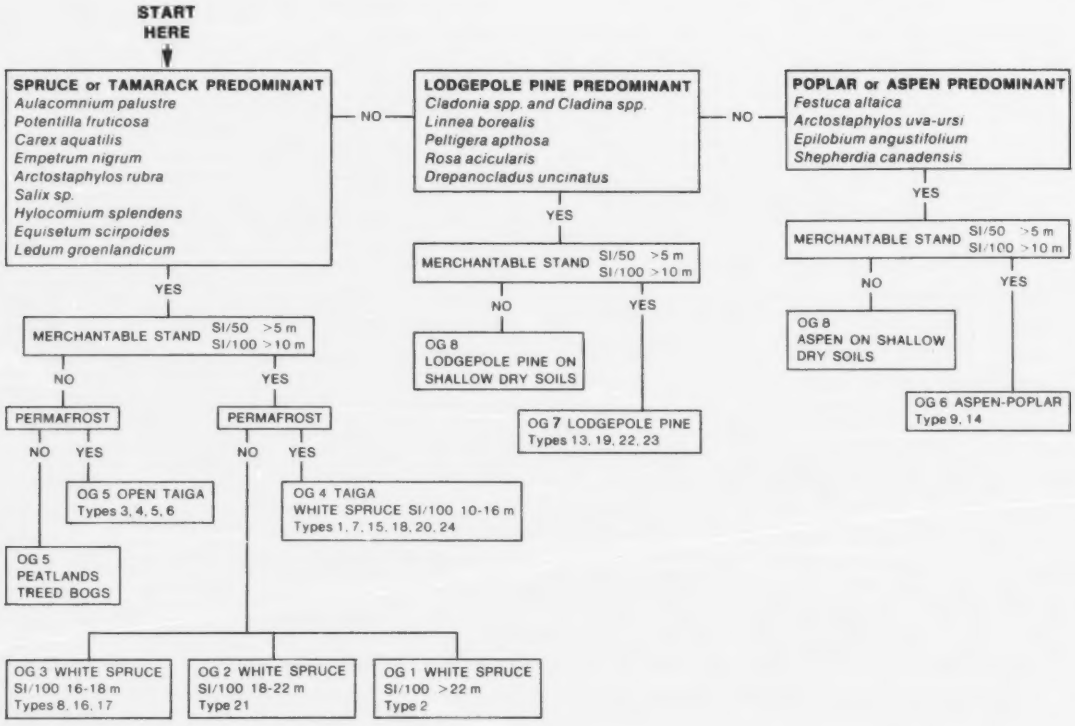

Figure 3. Flow diagram — key identifying operational groups (OGs) of forests along the Alaska Highway, Yukon Territory. Type numbers given in operational groups are identical to those in the "Descriptions and Examples of Operational Groups." The species are members of a group described on the basis of characteristic combination of frequent species and are listed in descending order of frequency values.

could not be penetrated by a simple soil auger to a depth of 10 cm. By September, in contrast to permafrost, the seasonal frost will have thawed.

Assignment of forest types to operational groups by site index is used only in spruce stands owing to the range of sites with that species. Pure lodgepole pine and poplar or aspen stands appeared less variable in height growth. Based on our survey, trees of better growth appeared to occur mainly in mixed stands.

Descriptions and examples of operational groups

Descriptions of each operational group are followed by one or several examples of pertinent forest types. The indicated tree heights are at the age of 100 years. The operational groups are arranged by key species, i.e., *Picea*, *Pinus* and *Populus*, and within each species they are arranged by decreasing site index. Type numbers and most of the botanical names coincide with those in Orlôci and Stanek (1979).

The soil types follow the classification defined by the Canada Soil Survey Committee (1978). The spread of horizons in the soil profiles indicates the ranges of horizon thickness found in the soils of the surveyed plots. The soil texture and soil moisture regime for soils without permafrost were assessed according to Table A in Appendix A of Bates et al. (1982) and soils with permafrost or prolonged seasonal frost were assessed according to Table A2 in Appendix A of Bates et al. 1982. Abbreviations used in the descriptions are explained in the Glossary.

Throughout the inspected areas, most of the coarse silty to coarse loamy soils contained 2 to 10% clay, 2 to 40% silt, 20 to 70% sand, and 2 to 20% gravel, cobbles and boulders. Chemical analyses were conducted on the upper 50 cm of the soil; the contents of exchangeable nitrogen, phosphorous and potassium were low, exchangeable calcium was medium to high, and exchangeable magnesium was low to moderate; the pH in H_2O ranged from slightly acidic to slightly alkaline.

The descriptions of the forest types are presented by memberships to operational groups rather than in the numerical order. The ecoregions (Figure 1) from which each forest type originates are also indicated. It has been shown that a forest type may occur in several ecoregions. Therefore, stratification by ecoregion was not deemed practical.

Operational Group 1:

White spruce — balsam poplar — fresh to moist — very good site quality — SI/100 over 22 m

In this group are found the most productive stands covered by this guide. The stands occur on nutritionally favorable sites with seepage on lower slopes or with access to ground water on bottoms of valleys and apparently stabilized floodplains or banks of rivers. These sites also appear to be sheltered against climatical adversities caused by wind and temperature extremes. Under those conditions, the manager has the choice of several harvesting methods (selective-, strip-, patch-, clear-cutting). The site is capable of producing saw or peeler logs. The projected management goal for a stand of white spruce is:

Rotation Age	Ave. Tree Ht. (m)	Ave. Tree dbh (cm)	Ave. Stand Basal Area (m^2/ha)	Merchantable Volume (m^3/ha)
100	22	35	50	300-400

The species composition may vary according to circumstances such as timing of planting, competition, and whether stands are left to regenerate naturally. Balsam poplar, especially, could make up a high proportion of the stands. Because of the high danger of blowdown, all harvesting operations, even clear-cutting, should be laid out so as to avoid wind damage along the edges of and in the remaining stands.

Reforestation with sturdy white spruce seedlings, preferably of local provenance, should follow immediately after harvesting. If nursery stock is not available or if successful seeding is cheaper than planting, natural reseeding may become the choice. In that case, harvesting in strips (up to about five tree lengths wide) or in patches (where necessary leaving up to twenty seed trees per ha) may become necessary. Site preparation by scarification may be required in case the logging operation did not create a suitable seed bed. On some sites, burning off the organic layers (duff) may become the only method effective in providing site preparation for reseeding or planting and ensuring site quality.

If it becomes necessary, poplars or poplar suckers may have to be removed by sanitation cutting or herbicide applications (injecting or painting stumps immediately after logging with 'Roundup' or 2,4-D Amine, for example).

If management for poplar is being considered as an alternative to white spruce, suitable, fast-growing clones could be introduced.

In many instances, stands in this operatinal group lack natural regeneration of white spruce, owing perhaps to an unsuitable seedbed (the organic layer may be too thick) or the dense canopies of the main stand. Therefore, artificial regeneration is important as is the selection of the most genetically suitable provenance.

These sites frequently provide wildlife shelter and management may consider harvesting in patches or strips to create openings in support of wildlife.

Example: Ecoregion 9, Vegetation Type 2: *Picea-Viburnum-Drepanocladus*

Forest cover: Mixed stands of varying proportions of white spruce and balsam poplar, black spruce, and occasionally paper birch

SI/100: White spruce: 27 m; Poplar: 29 m

Shrubs: *Alnus incana*
Salix sp.
Viburnum edule
Alnus crispa
Arctostaphylos rubra (dwarf shrub)
Vaccinium vitis-idaea (dwarf shrub)

Ground cover: *Mertensia paniculta* (herb)
Drepanocladus uncinatus (moss)
Hylocomium splendens (moss)
Equisetum arvense (horsetail)

Permafrost: None

Soil type: Regosols and Eutric Brunisols, occasionally gleyed; LFH horizon 2-9 cm

Soil texture: Coarse and fine silty

Soil pH: In H_2O 7.0-7.5

Moisture regime: Fresh to moist

Operational Group 2:

Spruce with admixtures of lodgepole pine and aspen — fresh site — good site quality — SI/100 for white spruce is from 18 to 22 m

The mainly fresh sites, somewhat less favorable nutritionally than those in operational group 1, support good-growing white spruce, aspen, lodgepole pine, and, in more moist phases, black spruce. Porous soils provide for rapid drainage. The seasonal frost which frequently persists during the growing season restricts water movement and keeps moisture in the soil. The stand history greatly influences the stand composition which ranges from aspen-pine-spruce to white and black spruce with diminishing aspen and pine component, to almost pure black spruce where buildup of organic layers prevents regeneration of white spruce. The choice of several harvesting methods is available (see operational group 1) but clear-cutting is almost exclusively used. Planting with vigorous white spruce seedlings should take place immediately after logging. Aspen suckers could interfere with the establishment of conifers. Repeated release of the conifers may become necessary at intervals of 10 to 15 years.

Considering the growth pattern of the stands, the optimum projected rotation age would be 70 to 80 years. This strategy would provide for the maximum mean annual increment and produce a tree height of about 15 to 18 m and a dbh of 16 to 18 cm. If that is too small, longer rotation must be chosen. Leaving a few seed trees, and scarifying (mechanized logging may create sufficient seed beds), may help to establish

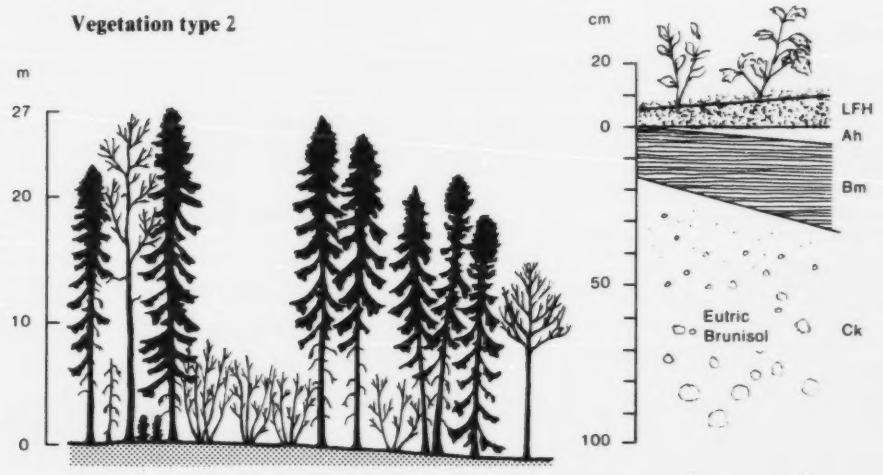

Figure 4. Vegetation type 2: average stand cross section at 100 years of age and soil profile.

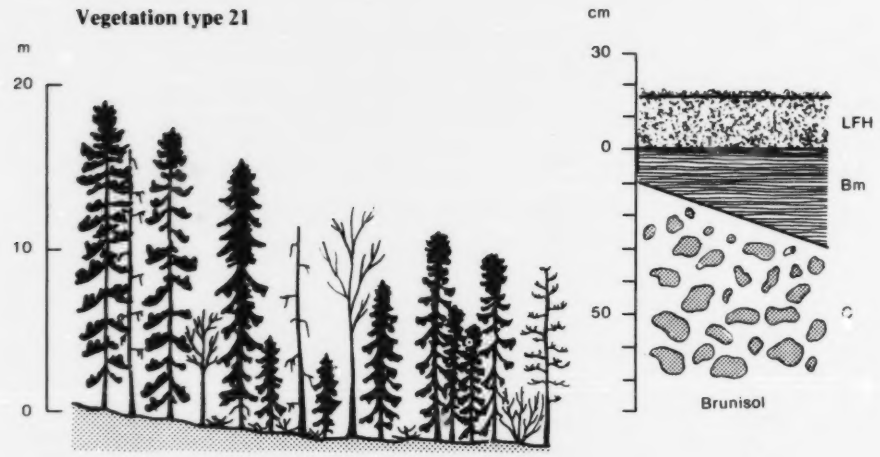

Figure 5. Vegetation type 21: average stand cross section at 100 years of age and soil profile.

lodgepole pine, especially where dry summer winds will lead to seed release.

Example: Ecoregion 2, Vegetation Type 21: *Picea-Hylocomium-Peltigera*

Forest cover: White spruce stands with admixtures of lodgepole pine, aspen, and black spruce. Regeneration of white spruce is present among the sometimes dense undergrowth of alder.

SI/100: white spruce: 19 to 20 m

Shrubs: *Ledum groenlandicum*
Vaccinium vitis-idaea (dwarf shrub)
Linnaea borealis (dwarf shrub)
Alnus crispa

Ground cover: *Hylocomium splendens* (moss)
Thuidium abietinum (moss)
Cornus canadensis (herb)
Pleurozium schreberi (moss)
Peltigera aphthosa (lichen)

Permafrost: None

Soil type: Mainly Eutric and occasionally Dystric Brunisols, frequently gleyed. LFH horizon may be up to 17 cm deep.

Soil texture: Loamy skeletal on gravel

Soil pH: In H_2O 5.0 to 7.0

Moisture regime: Fresh

Operational Group 3:

White spruce (often mixed with other species) — fresh to moist site — medium to good site quality — SI/100 11 to 18 m

In general, this operational group occupies alluvial sites. Combined with the absence of permafrost in the upper 1 m of soil, the moisture relationships of these sites provide relatively good conditions for tree growth. If undisturbed, these stands are well stocked and sometimes contain a hardwood component, but natural white spruce regeneration is often absent. Depending on site, the rotation age would range from about 80 to 120 years.

The stands lend themselves to selective-, strip-, or seed-tree logging. The method most likely chosen will be clear-cutting; it is simple and efficient, although not always environmentally sound on sites prone to instability. If cost-effective, clear-cutting at 80 to 120 years rotation followed by reforestation with vigorous white spruce (2/1 or 2/2-stock or plugs) at about 2000 seedlings per ha should be undertaken.

In most cases, poplars or aspens could attain merchantability but are not utilized. Therefore, emphasis should be placed on white spruce. Young stands would benefit from filling-in with suitable white spruce stock. When the stands contain natural regeneration of white spruce, one could assume that sowing would have some success. On morainic sites there may be a potential for new species such as the birdseye birch (variety of *Betula verrucosa*), which in Finland is grown for its

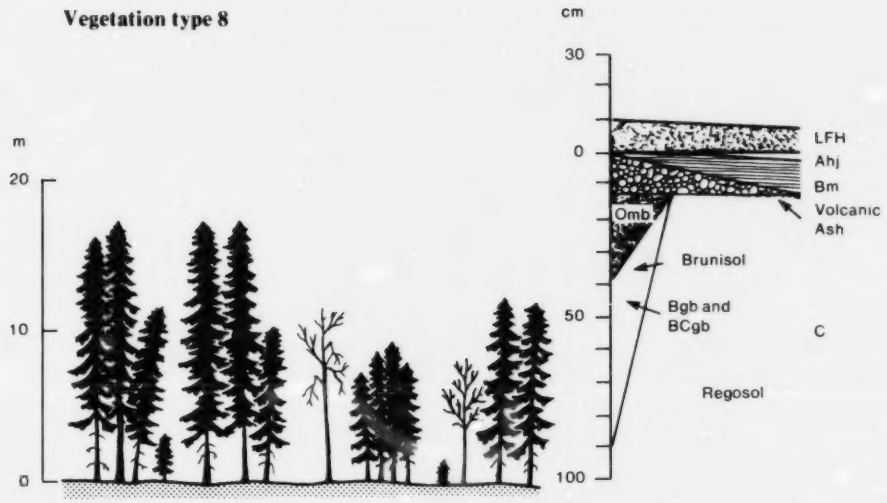

Figure 6. Vegetation type 8: average stand cross section at 100 years of age and soil profile.

valuable wood.

In mixed stands of spruce and lodgepole pine, reforestation with vigorous 2/0 white spruce or 1/0 lodgepole pine should follow immediately after logging. Nonregenerating burns should be reforested before competition sets in. Regenerating but understocked burned areas require filling-in, preferably with 2/1 white spruce. The seed should be of suitable provenance. If these stands are fertilized, a slow-releasing NP fertilizer such as urea formaldehyde or ground rock phosphate should be used.

Do not clear-cut potentially unstable slopes (the stability of a slope will depend on how much mechanical protection the forest provides to a specific site). Controlled burning could be considered as a means of removing the undesirable surficial organic layer (duff). Under certain circumstances, the duff layer prevents natural regeneration, makes tree planting difficult, and, if not checked at the time of stand establishment, could lead to worsening of growing conditions as sites become wetter and colder.

Example: Ecoregion 8, Vegetation Type 8: *Picea-Carex*

Forest cover: White spruce stands among the most common forest types in areas undisturbed by fire, occasional poplars (balsam or aspen) often poorly growing, being replaced by white spruce.

SI/100: white spruce: 17 m

Shrubs: *Salix* sp.
Linnea borealis (dwarf shrub)

Ground cover: *Carex concinna* (sedge)
Hylocomium splendens (moss)
Drepanocladus uncinatus (moss)
Epilobium angustifolium (herb)
Peltigera canina (lichen)
Lupinus arcticus (herb)

Permafrost: None

Soil type: Regosols and Brunisols with frost gleying. During droughty periods, a superficial carbonate crust may occur. In those locations, a fine and medium angular and subangular blocky structured B horizon may have developed. LFH horizon up to 10 cm.

Soil texture: Mainly sandy skeletal with gravel; occasionally sandy loam

Soil pH: In H_2O 5.5 to 8.0

Moisture regime: Very fresh to moist

Example: Ecoregion 5, Vegetation Type 16: *Picea-Hylocomium-Peltigera*

Forest cover: White spruce stands with admixtures of lodgepole pine and aspen, occasional regeneration of white spruce.

SI/100: white spruce: 16 m

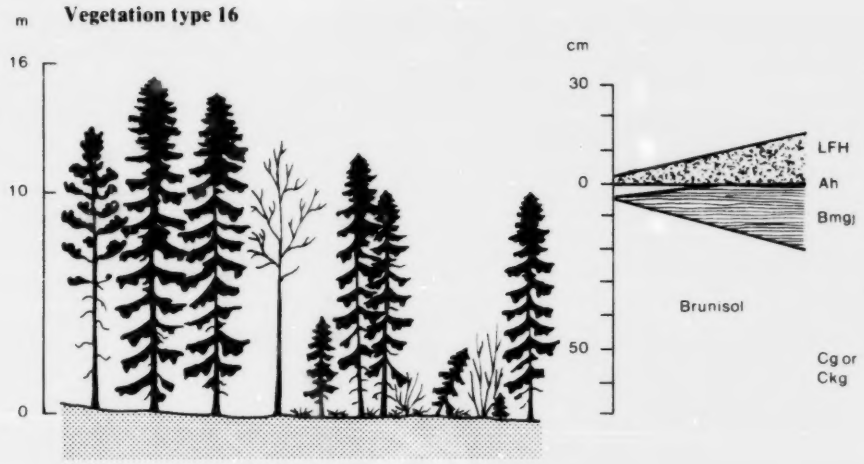

Figure 7. Vegetation type 16: average stand cross section at 100 years of age and soil profile.

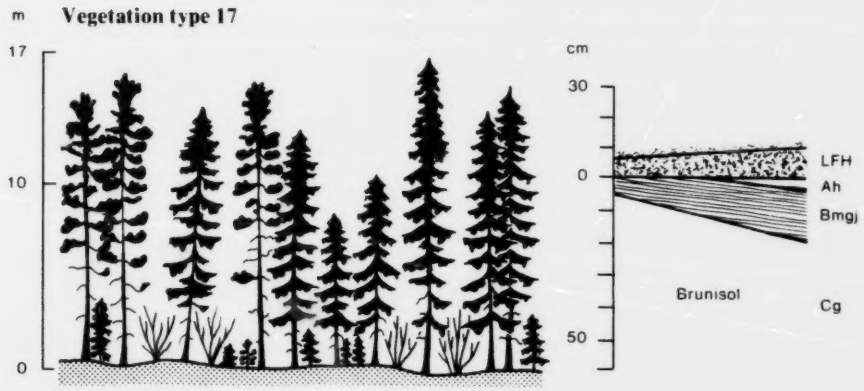

Figure 8. Vegetation type 17: average stand cross section at 100 years of age and soil profile.

Shrubs: *Salix* sp. (several species)
Ledum groenlandicum
Arctostaphylos uva-ursi (dwarf shrub)
Vaccinium vitis-idaea (dwarf shrub)
Linnaea borealis (dwarf shrub)

Ground cover: *Hylocomium splendens* (moss)
Peltigera aphthosa (lichen)
Pleurozium schreberi (moss)
Thuidium abietinum (moss)

Permafrost: None

Soil type: Generally Eutric Brunisols, occasionally Regosols, gleying frequent. LFH horizon rarely more than 15 cm.

Soil texture: Coarse loamy on gravel

Soil pH: In H_2O 6.0 to 7.0

Moisture regime: Moist

Example: Ecoregion 4, Vegetation Type 17: *Picea-Cornus-Hylocomium*

Forest cover: Varying proportions of white spruce and lodgepole pine

SI/100: Lodgepole pine: 16.5 m; white spruce: 17.5 m

Shrubs: *Salix* sp.
Salix glauca
Vaccinium vitis-idaea (dwarf shrub)
Empetrum nigrum (dwarf shrub)
Linnaea borealis (dwarf shrub)

Ground cover: *Hylocomium splendens* (moss)
Pleurozium schreberi (moss)
Festuca altaica (grass)
Cornus canadensis (herb)
Lupinus arcticus (herb)
Peltigera aphthosa (lichen)

Permafrost: None

Soil type: Mainly Dystric Brunisols; when drainage is impeded, gleying (frost gleying) occurs. LFH horizon up to 10 cm.

Soil texture: Coarse loamy

Soil pH: In H_2O 4.0 to 6.0

Moisture regime: Ranges from moist to wet

Operational Group 4:

White and/or black spruce — marginally merchantable- permafrost or wet site — poor to medium site quality — SI/100 for white spruce is from 10 to 16 m

The moist to moderately wet sites support rather open and poorly stocked, frequently overmature stands of mainly white spruce. Stands affected by beaver damming, flooding or impeded drainage of creek bottoms belong in this operational group. Natural regeneration is lacking; poor decomposition and accumulation of organic matter prevail; and the sites tend to become wetter with increasing stand age. In a few instances tamarack fens are found. Occasionally there is a dense shrub growth present (mainly willow). The trees appear to suffer from a high water table, and the larger trees show damage by wind owing to shallow root systems. In most instances these sites are a preferred wildlife habitat and, as such, merit protection.

The ground frost lasts long into the summer or even autumn. Ideally, the area should be drained, scarified or control burned, and reforested with about 1000 healthy white spruce seedlings per hectare. Where economically feasible, fertilization (mainly P and N) will enhance conditions for tree growth. Exposure of permafrost on slopes could lead to thaw flow or slump and slides. Keeping stands open and undergrowth from becoming dense would benefit tree growth by increasing the ground temperature.

Example: Ecoregion 9, Vegetation Type 1: *Picea-Ledum-Hylocomium*

Forest cover: Black spruce with sporadic white spruce; sometimes, based on twig characteristics, the two species are hard to distinguish.

SI/100: white spruce: 10 m

Shrubs: *Ledum groenlandicum*
Vaccinium vitis-idaea (dwarf shrubs)
Empetrum nigrum (dwarf shrub)
Vaccinium uliginosum
Salix sp.

Ground cover: *Hylocomium splendens* (moss)
Calamagrostis purpurascens (grass)
Thuidium abietinum (moss)
Equisetum scirpoides (horsetail)

Permafrost: Frequent, generally at depth of 60 to 100 cm

Soil type: Gleysolic Cryosol or Brunisolic Cryosol. LFH horizon to 25 cm

Soil texture: Coarse silty (sandy loam to very fine sand), usually mixed with boulders and gravel

Soil pH: In H_2O 4.5 to 6.5

Moisture regime: Very moist to wet

Example: Ecoregion 8, Vegetation Type 7: *Picea-Arctostaphylos-Thuidium*

Forest cover: White spruce stands occasionally with a minor black spruce component; frequently groups of overmature trees among small openings with mainly white spruce regeneration.

SI/100: white spruce 10 m

Shrubs: *Salix* sp.
Vaccinium vitis-idaea (dwarf shrub)
Arctostaphylos rubra (dwarf shrub)
Ledum groenlandicum
Empetrum nigrum (dwarf shrub)

Ground cover: *Thuidium abietinum* (moss)
Hylocomium splendens (moss)
Carex concinna (sedge)
Equisetum scirpoides (horsetail)

Permafrost: Frequent, generally at 1-m depth

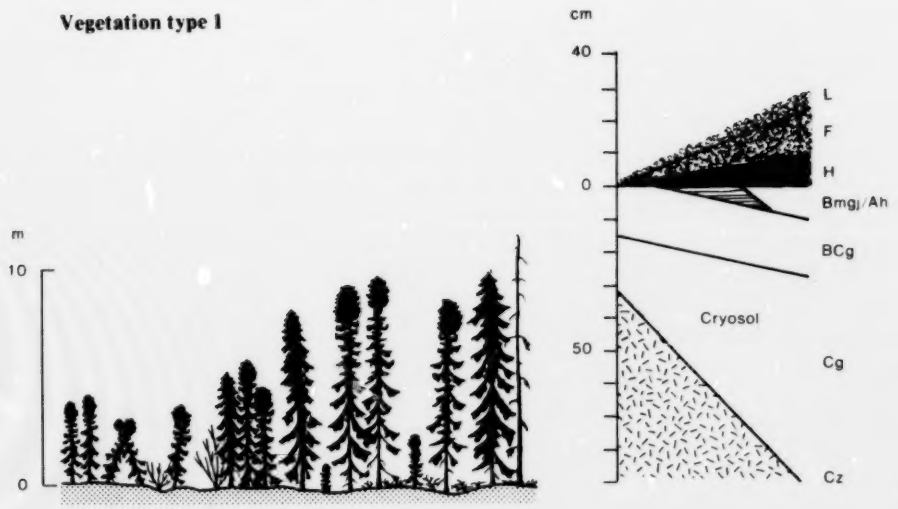

Figure 9. Vegetation type 1: average stand cross section at 100 years of age and soil profile.

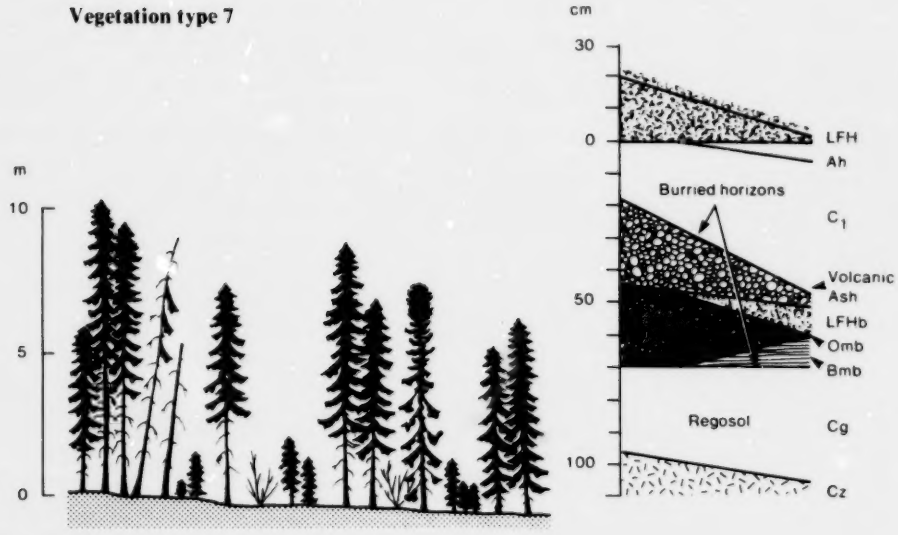

Figure 10. Vegetation type 7: average stand cross section at 100 years of age and soil profile.

Soil type: Though in a permafrost area, soils rarely qualify as Cryosols; many are Cumulic Regosols or Brunisols, gleying (frost gleying) is common. LFH horizon rarely more than 20 cm.

Soil texture: Mainly fine silty on gravel

Soil pH: In H_2O 5.5 to 7.5

Moisture regime: Very moist

Example: Ecoregion 5, Vegetation Type 15: *Picea-Arctostaphylos-Aulacomnium*

Forest cover: White and black spruce stands on topogenic organic accumulations, permafrost, and soils prone to frost gleying

SI/100: white spruce: 9 to 11 m

Shrubs: *Arctostaphylos rubra* dwarf
Salix myrtillifolia
Salix sp.
Ledum groenlandicum

Ground cover: *Aulacomnium palustre* moss
Peltigera aphthosa lichen
Equisetum scirpoides horsetail
Carex concinna sedge

Permafrost: Frequent, at depth from 65 to 100 cm

Soil type: Commonly Gleysolic Static Cryosols with LFH or O horizons usually up to 40 cm

Soil texture: Fine loamy

Soil pH: In H_2O 5.5 to 7.0

Moisture regime: Moist to wet

Example: Ecoregion 4, Vegetation Type 18: *Picea-Salix-Aulacomnium*

Forest cover: White spruce with admixture of black spruce and undergrowth of willow, birch and rarely alder

SI/100: white spruce: 16 m

Shrubs: *Salix* sp.
Salix myrtillifolia
Vaccinium vitis-idaea (dwarf shrub)
Rosa acicularis
Linnaea borealis (dwarf shrub)

Ground cover: *Hylocomium splendens* (moss)
Aulacomnium palustre (moss)
Drepanocladus uncinatus (moss)
Pleurozium schreberi (moss)
Peltigera aphthosa (lichen)
Equisetum scirpoides (horsetail)

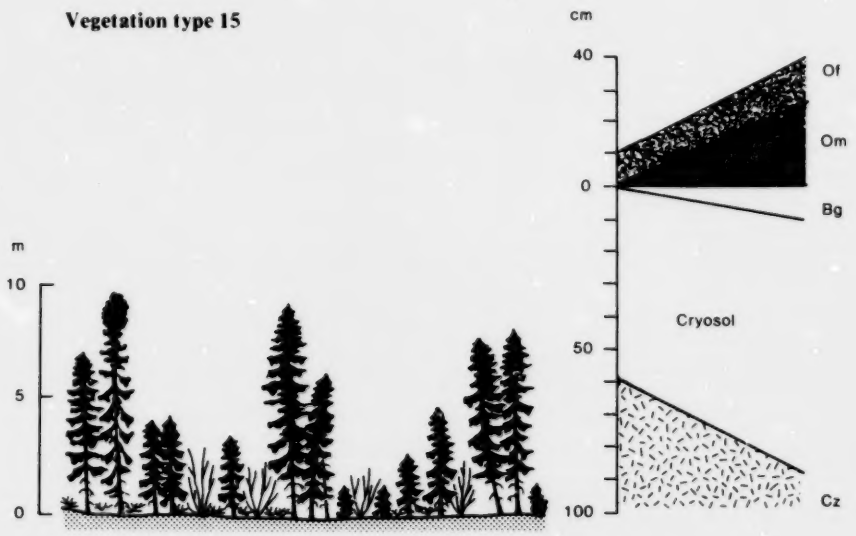

Figure 11. Vegetation type 15: average stand cross section at 100 years of age and soil profile.

Vegetation type 18

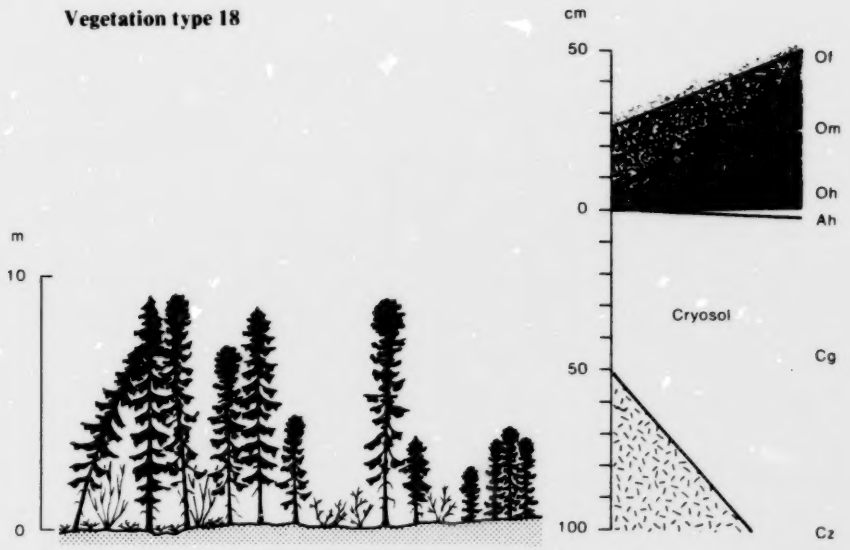

Figure 12. Vegetation type 18: average stand cross section at 100 years of age and soil profile.

Permafrost: Infrequent at a depth of 61 to 100 cm, ground frost long lasting

Soil type: Rego Gleysol or Gleysolic Static Cryosol. O horizons up to 50 cm.

Soil texture: Fine loamy to fine silty

Soil pH: In H_2O 5.9 to 7.1

Moisture regime: Moist to wet

Example: Ecoregion 4, Vegetation Type 20: *Picea-Salix-Carex-Aulacomnium*

Forest cover: Relatively open white and black spruce forest/shrub community in marshy sites often along streams

SI/100: white spruce: 9 to 14 m

Shrubs: *Salix myrtillifolia*
Salix sp.
Ledum groenlandicum
Potentilla fruticosa
Betula glandulosa
Arctostaphylos rubra (dwarf shrub)

Ground cover: *Aulacomnium palustre* (moss)
Sphagnum magellanicum (moss)
Thuidium abietinum (moss)
Carex aquatilis (sedge)

Permafrost: Below 1 m

Soil type: Gleysols or Humic Gleysols. LFH or 0 horizon up to 25 cm

Soil texture: Coarse silty and fine loamy, often with substantial amounts of gravel and clay

Soil pH: In H_2O 5.6 to 7.5

Moisture regime: Moderately moist to moist

Example: Ecoregion 2, Vegetation Type 24: *Picea-Salix-Rubus-Aulacomnium*

Forest cover: Mainly open white spruce or tamarack stands on wet sites. Trees are barely merchantable but growth improves with drainage.

SI/100: white spruce: 9 to 16.5 m

Shrubs: *Arctostaphylos rubra* (dwarf shrub)
Salix sp.
Betula glandulosa
Linnaea borealis (dwarf shrub)
Ledum groenlandicum

Ground cover: *Aulacomnium palustre* (moss)
Carex aquatilis (sedge)
Rubus arcticus (herb)
Calamagrostis purpurascens (grass)
Hylocomium splendens (moss)

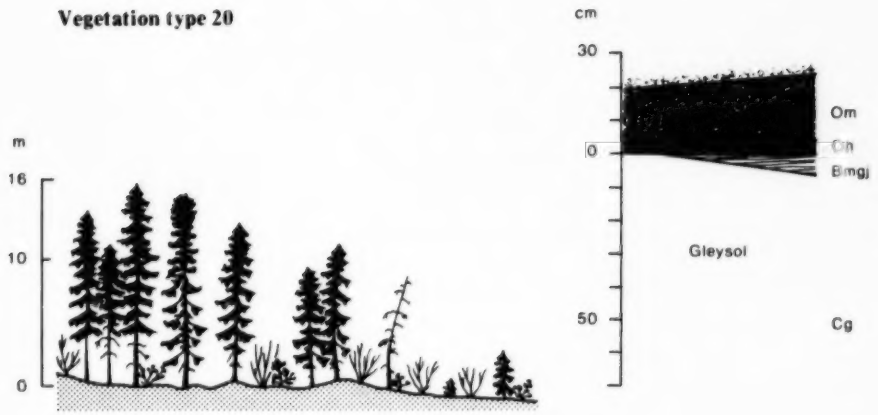

Figure 13. Vegetation type 20: average stand cross section at 100 years of age and soil profile.

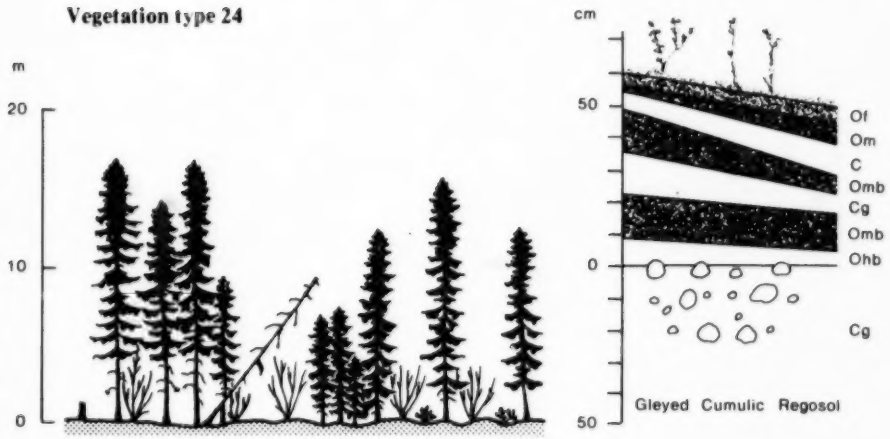

Figure 14. Vegetation type 24: average stand cross section at 100 years of age and soil profile.

Permafrost: Rare, ground frost long lasting

Soil type: Gleyed Cumulic Regosol. Cryosol rare. Cumulo Fibrisols occur. 0 horizon up to 60 cm.

Soil texture: Mainly gravel and sandy skeletal

Soil pH: In H_2O 5.8 to 7.5

Moisture regime: Very moist to wet (usually moving water)

Operational Group 5:

Black spruce and/or white spruce — nonmerchantable- permafrost site, usually wet — poor site quality

Permafrost and impeded drainage are the overriding factors that affect forest growth in this group. Discontinuous permafrost may allow drainage to improve tree growth, but at this time ameliorative measures are unlikely to bring economic returns. After disturbance such as construction, fire or thaw, willows dominate, with spruces gradually taking part in the plant com-

munity. After some decades, when the ground becomes insulated by undecomposed organic matter, the effect of permafrost increases, the active layer decreases in thickness, and drainage becomes restricted.

This operational group includes peatlands — specifically, treed bogs — which in the surveyed area are of negligible extent and limited to waterlogged depressions usually without permafrost.

Example: Ecoregion 9, Vegetation Type 3: *Salix-Carex*

Forest cover: Stunted, open growing willow-spruce wetland shrub type usually on disturbed sites (slide, solifluction, construction). May develop into a palsa.

SI/100: white spruce: 3 m

Shrubs: *Salix* sp.
Potentilla fruticosa

Ground cover: *Equisetum palustre* (horsetail)
Calamagrostis purpurascens (grass)
Eriophorum vaginatum (cotton grass)
Carex aquatilis (sedge)

Permafrost: Frequent at depth of < 60 cm

Soil type: Gleysolic, Static and Turbic Cryosols or Organic Cryosols; O horizon 25 to 70 cm.

Soil texture: Varies, usually fibric organic on top of fine loamy

Soil pH: In H_2O 6.5 to 7.6

Moisture regime: Moderately wet to very wet

Example: Ecoregion 9, Vegetation Type 4: *Picea-Ledum-Aulacomnium*

Forest cover: Unmerchantable, stunted, open growing black and white spruces taiga, in appearance similar to a treed bog

SI/100: white spruce: 6 m

Shrubs: *Ledum palustre*
Salix sp.
Vaccinium uliginosum
Vaccinium vitis-idaea (dwarf shrub)
Arctostaphylos rubra (dwarf shrub)

Ground cover: *Aulacomnium palustre* (moss)
Eriophorum vaginatum (cotton grass)
Sphagnum sp. (several species) (moss)
Hylocomium splendens (moss)
Equisetum scirpoides (horsetail)

Permafrost: In all soils at a depth of 30 to 60 cm

Soil type: Gleysolic, Turbic or Static Cryosols, always wet; organic soil usually less than 45 cm.

Soil texture: LFH or O fibric and mesic on fine loamy

Soil pH: In H_2O 4.5 to 6.8

Moisture regime: Moderately wet to very wet

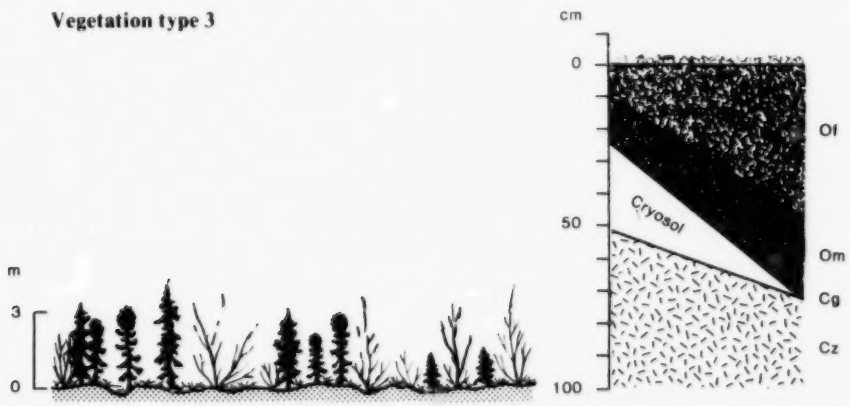

Figure 15. Vegetation type 3: average stand cross section at 100 years of age and soil profile.

Vegetation type 4

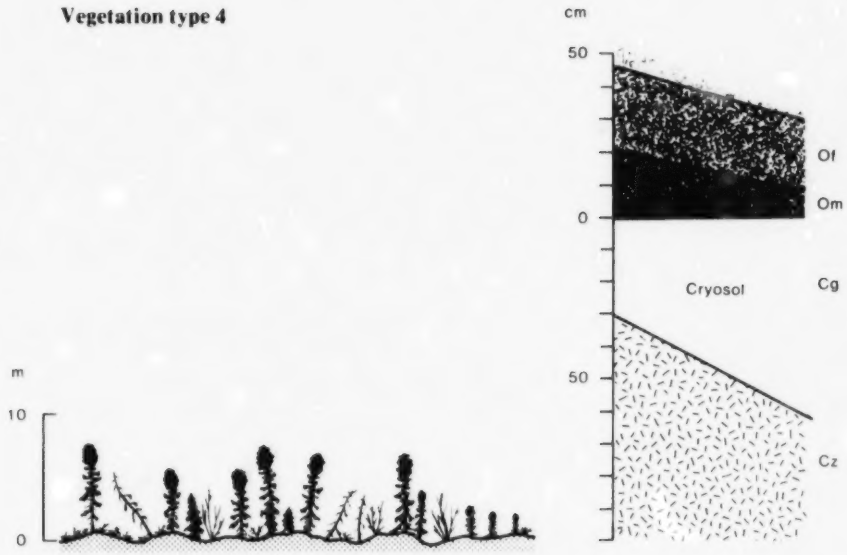

Figure 16. Vegetation type 4: average stand cross section at 100 years of age and soil profile.

Example: Ecoregion 8, Vegetation Type 5: *Picea-Rhododendron-Aulacomnium*

Forest cover: Treed bog-like taiga of white and black spruces

SI/100: white spruce: 9 m

Shrubs: *Vaccinium uliginosum*
Arctostaphylos rubra (dwarf shrub)
Rhododendron lapponicum (dwarf shrub)
Salix sp.
Ledum palustre
Vaccinium vitis-idaea (dwarf shrub)
Potentilla fruticosa

Ground cover: *Aulacomnium palustre* (moss)
Eriophorum vaginatum (cotton grass)
Equisetum scirpoides (horsetail)
Hylocomium splendens (moss)

Permafrost: At a depth of 60 cm

Soil type: Static and Turbic Cryosols and Organic Cryosols, frequently gleyed; the mainly fibric and mesic O horizon less than 60 cm.

Soil texture: Fine silty, often with gravel and stones

Soil pH: In H_2O 5.8 to 7.8

Moisture regime: Moderately wet to wet

Example: Ecoregion 8, Vegetation Type 6: *Salix-Picea*

Forest cover: Wetland shrub type with generally widely spaced white spruce pushing through willow thickets. Willow (*Salix glauca*) may attain 7 m and a dbh of 5 cm on disturbed sites (floodplains, fire and grazing sites). Occurs also just below the submontane zone and on calcareous material.

SI/100: white spruce: 9 m

Shrubs: *Salix* sp.
Arctostaphylos rubra (dwarf shrub)

Ground cover: *Aulacomnium palustre* (moss)
Carex aquatilis (sedge)

Permafrost: Occasionally found at a depth of 35 to 95 cm

Soil type: Mainly Gleyed Cumulic Regosols and Gleysols, LFH horizon 4 to 20 cm

Soil texture: Mainly sand and coarse loamy, some gravel and stones

Soil pH: Usually higher than 7.0 in H_2O

Moisture regime: Moist to moderately wet

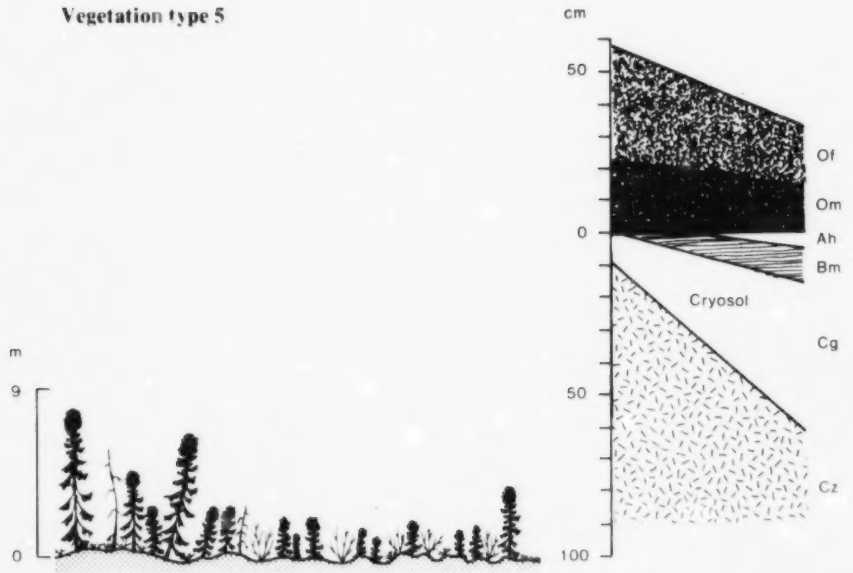

Figure 17. Vegetation type 5: average stand cross section at 100 years of age and soil profile.

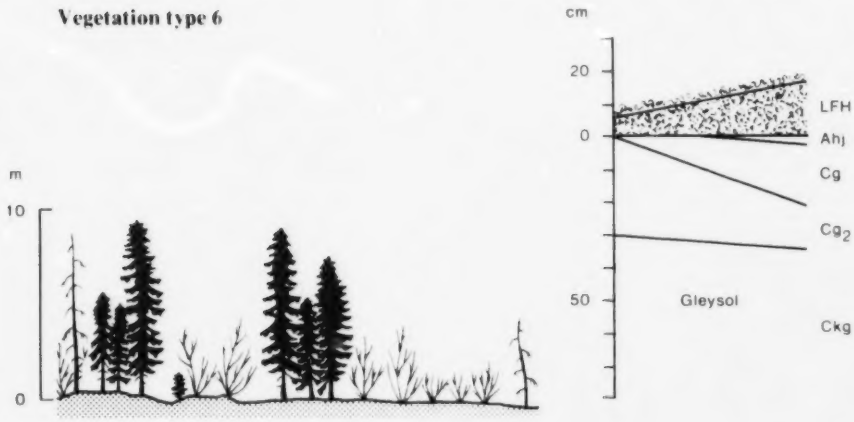

Figure 18. Vegetation type 6: average stand cross section at 100 years of age and soil profile.

Operational Group 6:

Poplar or aspen stands on fresh sites — good site quality — SI/100 for aspen is from 18 to 21 m

This operational group contains multilayered, open-canopied forests with a dominant deciduous component. Balsam poplar is most frequent on old floodplains, but aspen preferentially occupies slopes with southerly exposure.

In this operational group, harvesting depends on the size of trees and the market situation. Sites with a potential for good productivity should be utilized for veneer log production. In most cases, underplanting of open stands and filling-in with white spruce — or, as a second choice, trials of suitable poplar clones — should be considered.

Example: Ecoregion 8, Vegetation Type 9: *Picea-Arctostaphylos-Festuca, Populus balsamifera* variant

Forest cover: Open canopied, multilayered balsam poplar stands with admixtures of white spruce and occasionally of lodgepole pine or open stands of white spruce with a high component of poplars. Stands appear successional between pioneer stands after fire and white spruce old growth.

SI/100: white spruce: 15 m

Shrubs: *Arctostaphylos uva-ursi* (dwarf shrub)
Salix sp.
Shepherdia canadensis
Rosa acicularis

Ground cover: *Festuca altaica* (grass)
Epilobium angustifolium (herb)
Lupinus arcticus (herb)

Permafrost: None

Soil type: Mainly Eutric Brunisols trending toward Melanic Brunisols; also Cumulic Regosols. LFH horizon less than 10 cm. Frost gleying occurs.

Soil texture: Coarse loamy on top of gravel

Soil pH: In H_2O frequently above 7.0

Moisture regime: Moderately dry to fresh

Example: Ecoregion 5, Vegetation Type 14: *Populus-Arctostaphylos-Shepherdia*

Forest cover: Aspen stands interspersed with either lodgepole pine or white spruce, the latter species usually in undergrowth gradually replacing the former two

SI/100: white spruce: 18 to 20 m

Shrubs: *Arctostaphylos uva-ursi* (dwarf shrub)
Linnaea borealis (dwarf shrub)
Shepherdia canadensis
Rosa acicularis
Salix sp.

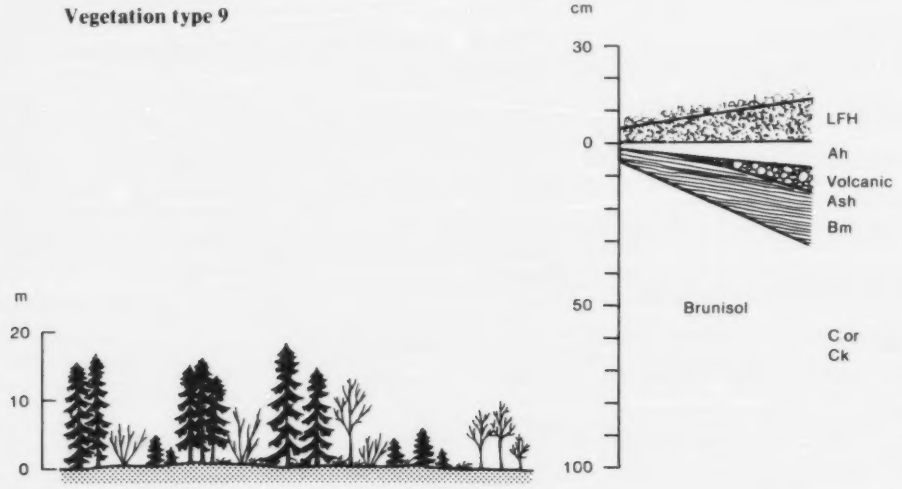

Figure 19. Vegetation type 9: average stand cross section at 100 years of age and soil profile.

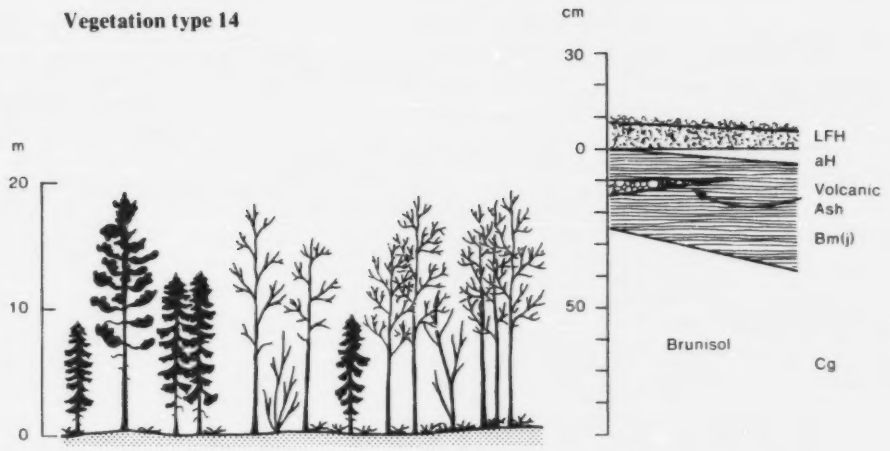

Figure 20. Vegetation type 14: average stand cross section at 100 years of age and soil profile.

Ground cover: *Epilobium angustifolium* (herb)
Lupinus arcticus (herb)
Hylocomium splendens (moss)
Pleurozium schreberi (moss)
Cornus canadensis (herb)

Permafrost: None

Soil type: Generally Eutric Brunisol, occasional Regosol. LFH horizon up to 9 cm deep

Soil texture: coarse silty on top of gravel

Soil pH: In H_2O 5.9 to 7.6

Moisture regime: Moderately dry to fresh

Operational Group 7:

Lodgepole pine pure or mixed with some white spruce — moderately dry to moderately fresh site — medium to good site quality — SI/100 for lodgepole pine is up to 14 m, rarely more; or lodgepole pine pure or mixed with some black spruce — fresh sites — medium site quality — SI/100 for lodgepole pine is about 12 m; SI/100 for black spruce is about 13 m

Most lodgepole pine stands originated after fire and they are even-aged and often overstocked. The present harvesting in 20 ha (about 500 by 400 m) blocks should be followed by planting seedlings of lodgepole pine or white spruce or, on wetter sites, black spruce.

Depending on site conditions after logging, scarification with natural reseeding and, where required, with seeding of lodgepole pine of local origin. Where warranted, seeding with local provenances of white spruce could be tried.

Example: Ecoregion 5, Vegetation Type 13: *Pinus-Arctostaphylos-Festuca*

Forest cover: Lodgepole pine stands, with accompanying aspens. White spruce and occasionally lodgepole pine regeneration, and aspen suckers

SI/100: lodgepole pine: 14 m

Shrubs: *Arctostaphylos uva-ursi* (dwarf shrub)
Vaccinium vitis-idaea (dwarf shrub)
Viburnum edule
Rosa acicularis
Linnaea borealis (dwarf shrub)

Ground cover: *Festuca altaica* (grass)
Peltigera aphthosa (lichen)
Cladonia arbuscula (lichen)

Permafrost: None

Soil type: Generally Eutric and Dystric Brunisols; occasional Regosols. Frost gleying common. LFH horizon up to 20 cm.

Soil texture: Coarse loamy

Soil pH: In H_2O 5.1 to 7.4

Moisture regime: Moderately dry to moderately fresh

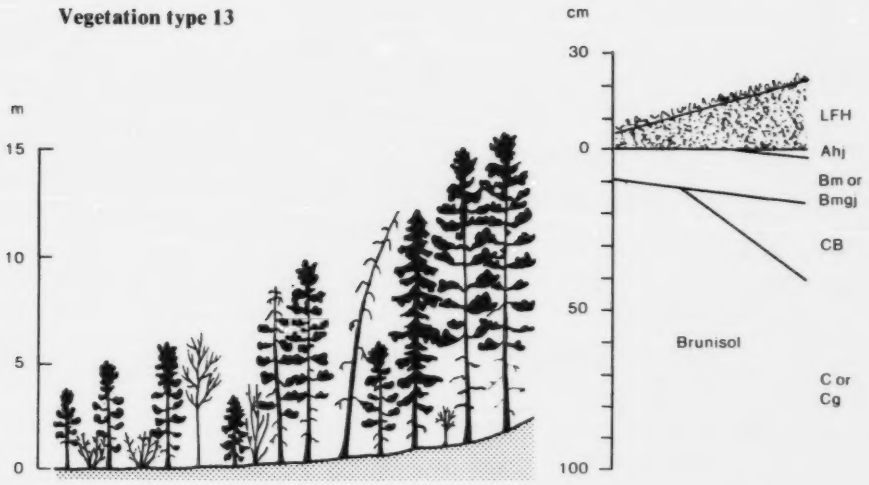

Figure 21. Vegetation type 13: average stand cross section at 100 years of age and soil profile.

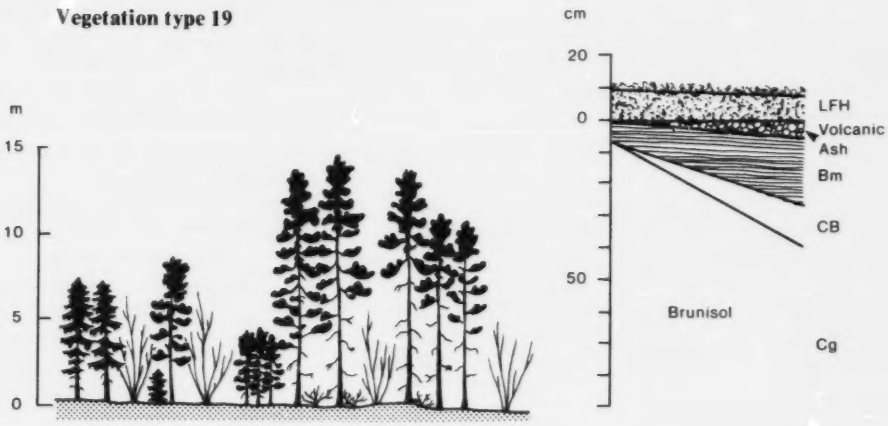

Figure 22. Vegetation type 19: average stand cross section at 100 years of age and soil profile.

Example: Ecoregion 4, Vegetation Type 19: *Pinus-Festuca-Peltigera*

Forest cover: Generally even-aged, 30 to 60 years old lodgepole pine stands of fire origin. Occasionally white spruces are regenerating underneath the canopy with willows and birch frequently present.

SI/100: lodgepole pine: 15 to 19 m

Shrubs: *Linnaea borealis* (dwarf shrub)
Vaccinium vitis-idaea (dwarf shrub)
Vaccinium uliginosum
Ledum groenlandicum
Salix (several species)
Betula glandulosa

Ground cover: *Festuca altaica* (grass)
Peltigera aphthosa (lichen)
Epilobium angustifolium (herb)
Lupinus arcticus (herb)
Drepanocladus uncinatus (moss)
Pleurozium schreberi (moss)
Cornus canadensis (herb)

Permafrost: None

Soil type: Generally Dystric Brunisol and Regosols. Gleying and frost gleying present. LFH horizon up to 10 cm.

Soil texture: Sandy skeletal or loamy skeletal with 30 to 50% coarse fragments (gravel or stones)

Soil pH: In H_2O 5.0 to 6.0

Moisture regime: Moderately dry to moderately fresh

Example: Ecoregion 2, Vegetation Type 22: *Pinus-Vaccinium-Hylocomium*

Forest cover: Barely merchantable lodgepole pine stands of fire origin with varying admixtures of mainly black spruce and occasionally aspen

SI/100: lodgepole pine: 13 m; black spruce: 12 m

Shrubs: *Vaccinium vitis-idaea* (dwarf shrub)
Alnus crispa
Ledum groenlandicum
Arctostaphylos uva-ursi (dwarf shrub)
Linnaea borealis (dwarf shrub)

Ground cover: *Hylocomium splendens* (moss)
Pleurozium schreberi (moss)
Peltigera aphthosa (lichen)
Cladonia arbuscula (lichen)
Cladonia ecmocyna (lichen)
Thuidium abietinum (moss)
Cladonia gracilis (lichen)
Cladina rangiferina (lichen)

Permafrost: None

Soil type: Commonly Dystric Brunisols, frequently eluviated, occasional Eutric Brunisols. LFH horizon up to 15 cm

Soil texture: Coarse loamy with 5 to 20% gravel and cobbles

Soil pH: In H_2O commonly below 6.0

Moisture regime: Fresh (mainly on account of frost gleying)

Example: Ecoregion 2, Vegetation Type 23: *Pinus-Vaccinium-Festuca*

Forest cover: Lodgepole pine or aspen or both species, usually of fire origin

SI/100: lodgepole pine: 16 m

Shrubs: *Vaccinium vitis-idaea* (dwarf shrub)
Arctostaphylos uva-ursi (dwarf shrub)
Shepherdia canadensis
Linnaea borealis (dwarf shrub)

Ground cover: *Festuca altaica* (grass)
Peltigera canina (lichen)
Epilobium angustifolium (herb)
Lupinus arcticus (herb)
Cladonia gracilis (lichen)

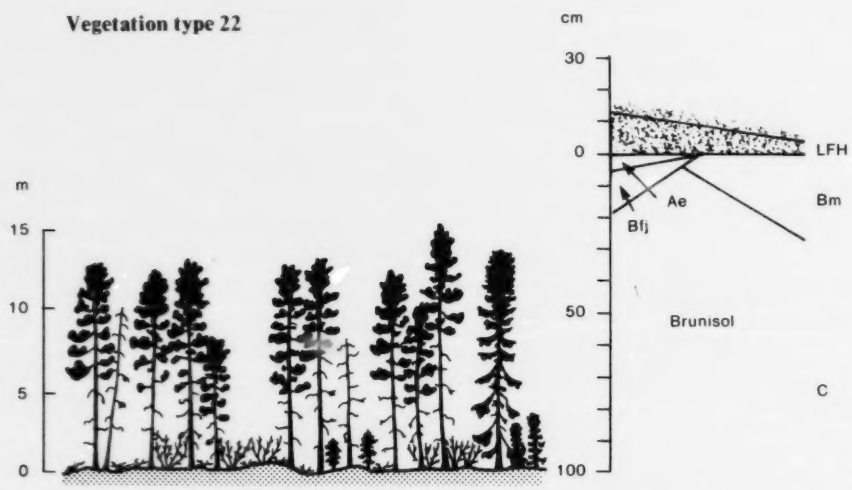

Figure 23. Vegetation type 22: average stand cross section at 100 years of age and soil profile

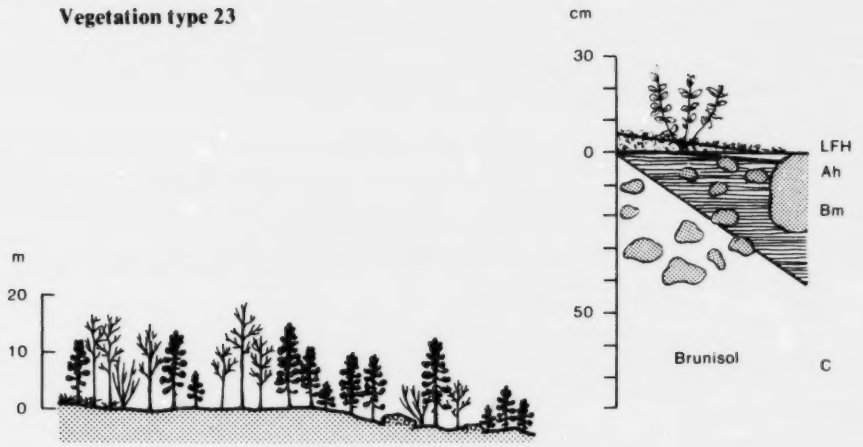

Figure 24. Vegetation type 23: average stand cross section at 100 years of age and soil profile.

Permafrost: None

Soil type: Generally Eutric Brunisols; occasional Regosols and Dystric Brunisols. LFH horizon up to 4 cm

Soil texture: Sandy skeletal with over 50% gravelstones

Soil pH: In H_2O 5.0 to 7.0

Moisture regime: Dry to moderately dry

Operational Group 8:

Coniferous and/or deciduous stands on extreme sites- usually unmerchantable or marginally merchantable- stands deserving protection from clear-cutting.

This operational group contains lodgepole pine or aspen stands, pure or mixed, on physiologically shallow sites (coarse textured, stony, rapidly draining, droughty soils). Usually these sites have been exposed to repeated fires. Most of the stands should be protected from any disturbance. The stands are usually in sensitive locations — at the foot of talus, sites bordering submontane slopes, dunes, in general on coarse detrital material — and should be maintained for site protection.

Site Index Estimation

The tree height or site index at 100 years (SI/100) is used to describe the growth potential of trees on a certain site. To construct height-age curves for estimation of the SI/100, published height-growth curves for lodgepole pine (Alemdag 1976; Thompson et al. 1984) and for white spruce (Farr 1967; Alemdag 1976) and field measurements of 150 lodgepole pines and 80 spruces were used. For white spruce, the curves from the literature were adjusted by the addition of 15 years to the breast-height age to get the total age. In the same manner, white spruce curves by Farr (1967) and Thompson et al. (1984) were adjusted by 5 years to account for ages determined at stump height. The adjustments are based on age counts on several sites.

The resulting empirical height growth curves (Figures 25 and 26) are presented for field estimation of the SI/100 for white spruce and lodgepole pine. The total age of the trees should be estimated either from available records or from growth-ring counts with the same allowance for years up to the height at which rings are counted. The heights of the tallest trees in the stand, as suggested in Farr (1967), should be measured. Averages derived from three to five individuals should suffice.

With the total age and the dominant stand height known, the site class of a stand may be directly read from the curves. According to Plonski (1974), sites known to be poor (for example, locations with very shallow soil, coarse soil material, waterlogging, or a shallow active layer) should be recorded as the lowest site class of the four shown in Figures 25 and 26, even if the present growth, judged from age and height, indicates a better site class. This applies particularly to young stands.

Figure 25. Height growth curves for white spruce. Site quality is indicated by Roman numerals. (I = very good; II = good; III = medium; IV = poor)

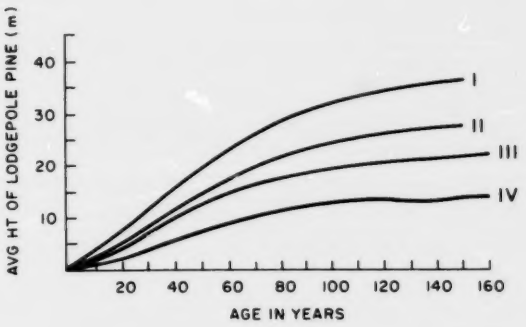

Figure 26. Height growth curves for lodgepole pine. Site quality is indicated by Roman numerals. (I = very good; II = good; III = medium; IV = poor)

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Glossary

A — mineral horizon formed at or near the surface in the zone of leaching or eluviation of materials in solution or suspension (Ae) or of maximum in situ accumulation of organic matter (Ah) or both (Ahe)

Ae — light colored near surface, eluvial horizon where leaching of dissolved or suspended souble salts, iron, aluminum, organic matter or clay takes place, and mainly poorly soluble materials such as quartz remain

Ah — dark coloured, mineral, horizon enriched with organic matter. In a well aerated soil, a well developed Ah usually indicates a good soil condition in that presence of organic matter increases the nutrient and water holding capacities

AB — a transition horizon from A to B

B — mineral horizon characterized by enrichment (illuviation) in organic matter (Bh), clay (Bt) or iron and aluminum sesquioxides (Bf)

b — buried by deposits of river, wind, volcano, etc.

BC — transition horizon from B to C

Bf,Bhf — Reddish brown subsurface horizon caused by significant illuviation (accumulation) of iron, aluminum and/or organic matter

Bfj — Juvenile Bf horizon

Bg — Gleyed B

Bj — Juvenile B

Bm — Brownish subsurface horizon with only slight illuviation of iron, aluminum or clay

Bmg — gleyed Bm

Brunisol — Order of soils, the profiles of which all have Bm or Btj, rusty colored, illuvial horizons. They are common in the surveyed area of the Yukon.

Btj — Horizon with some illuviation of clay

C — Mineral horizon comparatively unaffected by the pedogenic processes operative in A and B

Calcareous — Soils containing sufficient calcium carbonate to effervesce visibly when treated with dilute (0.1 N) hydrochloric acid.

Cg — Gleyed C

Ck — Horizon containing calcium and/or magnesium carbonates that will effervesce with dilute hydrochloric acid

Ckg — Gleyed Ck

Climax — Stage in plant succession for a given environment in which vegetation is assumed to have reached a highly stable condition

Clustering — Classification technique of data (such as presence or absence of plant species) whereby similar small groups are further combined according to their similarities into broader groups, thus forming a classification tree (dendrogram)

Cryosol — Mineral or organic soils that have perennially frozen material within 1 m of the surface

Cumulic Regosol — Soils in the Regosolic order that consist of depositions of soil material during flooding, sliding, windblowing, and show little or no weathering or soil horizon development

Cz — C horizon with permafrost

dbh — Diameter at breast height (1.3 m or 4 ft. 3 in.)

Dwarf shrub — Small woody plant, usually prostrate in the herb layer

Dystric Brunisol — Soils in the Brunisolic order that have an Ah horizon less than 10 cm thick, and a pH in 0.01 M $CaCl_2$ of less than 5.5

Ecosystem — Any area of nature that includes living and nonliving entities which interact

Eutric Brunisol — Soils in the Brunisolic order that may have an Ah horizon less than 10 cm thick and pH of more than 5.5

F — Organic fermentation layer, never waterlogged, that is characterized by an accumulation of partly decomposed organic matter in which most of the original structures are recognizable with difficulty

f — Horizon enriched with amorphous material, principally aluminum and iron

Fen — Meadow-like sedge-rich peatland on minerotrophic sites. Often there is a low shrub cover and sometimes a sparse layer of trees (Stanek and Worley 1983)

Fibric — Weakly decomposed organic matter whose botanical origin is readily identifiable

Forest type — Forest areas similar with respect to composition of vegetation layers (tree, shrub, herb, moss, epiphyte), type of wildlife, complex of climatic, hydrologic and pedogenic processes, mutual relationships between the plants and the surroundings, processes of regeneration, direction of vegetation successions, and, under the same economic conditions, silvicultural requirements. In the silvicultural sense, the forest type is equivalent to Tansley's (1935) ecosystem or Sukachev's (1954) biogeocoenosis, and has the same meaning as the terms "site" and "forest site."

Frost gleying — Process of gley formation by seasonal frost impeding drainage periodically beyond the winter even in rapidly pervious mineral soil materials

g — Gleyed horizon, characterized by bluish gray colors or prominent mottling or both, indicative of permanent or periodic waterlogging and oxygen loss

Gley — Soil developed under permanent or periodic waterlogging leading to oxygen reduction, e.g., from yellow-red ferric oxide (Fe_2O_3) to blue-gray ferrous oxide (FeO).

Gleysol — An order of soil in which gley is characteristic

h — Horizon enriched with organic matter

H — Organic humus layer, never waterlogged, that is characterized by an accumulation of decomposed (humic) organic matter in which most of the original structures are indiscernible

Humic — Highly decomposed organic soil material containing little or no fibrous constituents

j — Stands for "juvenile" and is used as a modifier of suffixes e, f, g, n, t to denote an undeveloped condition

k — Denotes the presence of carbonate as indicated by visible effervescence when a sample is tested with dilute hydrochloric acid

L — Organic litter layer, never waterlogged, that is characterized by an accumulation of undecomposed and more or less uncomminuted (fibric) organic matter in which the original structures are easily discernible

L,F,H, — Organic horizons, developed under terrestrial, nonwaterlogged conditions: L — litter layer, undecomposed (fibric); F — fermentation layer, partly decomposed (mesic); H — humus layer, well decomposed (humic)

m — Horizon slightly altered by hydrolysis, oxidation, or solution, or all three to give a change in color or structure; used only with B

Mesic — Organic material at a stage of decomposition intermediate between fibric and humic

Moisture regime — See Soil moisture regime

O (Of,Om,Oh) — Organic horizon (peat) developed under poor drainage conditions: Of — fibric, poorly decomposed; Om — mesic, moderately decomposed; Oh — humic, well decomposed

Ordination — Classification techniques that find the best fitting path through data clusters. In this report, component analysis is used whereby linear clusters of data are reduced to simpler components represented by suitable axes. The component scores are rectangular ordination coordinates. Thus, vegetational or environmental characteristics can be plotted to form a scatter diagram.

Palsa — Mound or plateau composed of an organic layer overlying mineral soil. It has a perennialy frozen core.

Permafrost — Thermal condition in soil or rock in which temperatures below 0°C persist over at least two consecutive winters and the intervening summer

Peatland — Areas having peat forming vegetation on peat (Stanek and Worley 1983)

pH — Negative logarithm of the hydrogen ion concentration of a soil: pH 7 is neutral; below 7 is acidic; above 7 is basic. For field use, pH tape or portable pH meters suffice.

Regosol — A Great Group in the Regosolic order characterized by insufficient horizon development

Seasonal frost — Freezing temperatures that keep the soil materials seasonally frozen. Under tree canopies or layers of organic materials, frozen soil can persist even with ambient air temperatures above 0°C.

Seasonally frozen ground — Ground affected by seasonal frost. In droughty sites or rapidly pervious soils, it may contribute to enhancement of soil moisture to benefit tree growth.

Scarification — Site preparation to facilitate regeneration of the forest. Corns and Annas (1986) differentiate the following types:

— low-intensity scarification on sites with less than 10 cm soil organic layer thickness using manual screefing or mechanical scarification by anchor chain or scarifier blade;

— medium-intensity scarification on sites with 10 to 15 cm organic matter using shark-fin barrels, scarifier blade or Bracke scarifier;

— high-intensity scarification on poorly drained sites with deep (15 to 30 cm) organic horizons using Marttliny plow or Craig and Simpson ripper plow, brush rake, scarifier blade or Cazes and Heppner plow.

Silviculture — The science and art of cultivating forest crops based on a knowledge of silvics: life history, characteristics, and ecology of forest trees esp. in stands

SI/100 — Site Index at the age of 100 years

Site Index — A measure of tree growth based on the height of the dominant trees in a stand at a selected age, e.g., 100 years

Site quality — Potential of a site to grow merchantable tree crops.

Soil moisture regime — Characteristic moisture condition of the soil environment

Soil particles — Soil separates

Submontane — Relating to or growing on high slopes below the timberline, synonym to subalpine

Taiga — Terrain with an open canopied and usually poorly developed tree layer, and permafrost within 1 m of the soil surface

Topogenic (ous) — Produced by relief

Tundra — Treeless terrain with permafrost within 1 m of the soil surface

Waterlogged — Saturated with water, flooded

z — Permafrost

Appendix A

Soil Moisture Regime

The soil moisture was determined according to the key in Bates et al. (1982) (Table A1). Because of permafrost, a modified soil moisture regime table (Table A2) was designed and used in the field to determine the soil moisture regime of soils with permafrost and with ground frost lasting into the growing season. In both these situations, the frost affects the drainage properties of the soil and the soil moisture regime. The frost thus overrides the potential pore pattern effect on the soil moisture regime. In most cases of permafrost, the active layer thickness determines the soil drainage. In case of ground frost, the depth of the frost-free soil and the duration of the ground frost have a similar effect on the soil drainage.

Table A1. Pore Pattern Soil Moisture Regime (These data are reproduced by permission of the Ontario Institute of Pedology)

DEEP MINERAL SOILS (>120 cm)

Perviousness class[1]	Pore pattern[1] of mineral soil materials: Examples of textures without compaction[2]	Pore pattern class/sym	SOIL MOISTURE REGIME[4]			
			Dry (d)		Fresh (f)	
			Dry	Mod. dry	Mod. fresh	Fresh
			0	0	1	2
Rapidly	All material >2.0 mm	Extremely open 0	All slopes 1			
	Very coarse and coarse sands: loamy very coarse and coarse sands	Very open 0		All slopes 2/1	g: 100-180 or G: 150-200 2/1	g: 80-100 or G: 120-150 4/5
	Medium sand, loamy medium sand	Open 1		All slopes 2	g: 100-180 or G: 180-240 2	g: 80-100 or G: 150-180 4/5
	Fine sand, loamy fine sand, silty fine sand	Moderately open 2			All slopes 2/3	g: 100-150 or G: 150-210 2/3
Moderately	Sandy loam, very fine sand; loamy very fine sand; silty very fine sand	Moderately retentive 3				All slopes 3
	Loam, silty loam, sandy clay loam, structured silty clay and clay (aggregates <10 mm)	Retentive 4				All slopes 3/4
	Silt, silty clay loam, clay loam; sandy clay, structured silty clay and clay (aggregates >10 mm	Very retentive 5			s >100% 3/4	s <100% 4/3
Slowly	Structureless silty clay and clay	Moderately restricted 6			s >70% 4	s <70% 4
	Porous or fractured bedrock	**Restricted to very restricted 7 8**				
	Non-porous bedrock	**Extremely restricted 9**				

1. **Pore Pattern** and Perviousness Classes indicate the numbers and sizes of spaces (pores) between the soil particles which determine the drainage and moisture retention characteristics of the soil. The classes are inferred from soil texture, structure and compaction.
2. Significant compaction can increase the pore pattern usually by one class (e.g. a 3 to 4).

Not considered as mineral soil.

SYMBOLS

g a mottled layer indicative of periodic saturation and aeration
g: 15-30 the top of the mottled layer lies between 15 and 30 cm below the mineral surface

G a grey gley layer indicative of prolonged saturation
G: 60-90 the top of the grey gley layer lies between 60 and 90 cm below the mineral surface
G: <45 the top of the grey gley layer lies within 45 cm of the mineral surface

s degree of slope which results in very rapid or rapid surface run off (p.40 CanSIS manual[3])

the 'normal' site with no slope or drainage restrictions

[3] Canada Soil Survey Committee, Working Group on Soil Survey Data, J. Dumanski, ed. 1978. revised. The Canadian Soil Information System (CanSIS), Manual for describing soils in the field. Land Resource Research Institute, Agriculture Canada, Ottawa, Ont.

ORGANIC SOILS[5]

SOIL MOISTURE REGIME[4]

Fresh (f)	Moist (m)			Wet (w)		
Very fresh	Mod. moist	Moist	Very moist	Mod. wet	Wet	Very wet
3	4	5	6	7	8	9
g: 50-80 or G: 90-120 4/5	g: 30-50 or G: 60-90 5/6	g: 15-30 or G: 45-60 6/7	g: 5-15 or G: < 45 7/6			
g: 50-80 or G: 90-150 4/5	g: 30-50 or G: 60-90 5/6	g: 15-30 or G: 45-60 6/7	g: 5-15 or G: < 45 7/6	Of: 60-160 or Om: 40-100 or Oh: 40-100 with g: 0-5	Of > 160 or Om > 100 or Oh > 100 with upper part not saturated all year and	Of > 160 or Om > 100 or Oh > 100 with saturation to surface all year and
g: 60-100 or G: 120-150 4/5	g: 40-60 or G: 60-120 5/6	g: 20-40 or G: 45-60 6/7	g: 5-20 or G: < 45 7/6			
g: 60-120 or G: 150-210 4/5	g: 40-60 or G: 90-150 5/6	g: 20-40 or G: 60-90 6/7	g: 5-20 or G: < 60 7/6	if g is > 5 use mineral soil criteria	G present to top of mineral soil	G present to top or mineral soil
g: 60-120 4/5	g: 45-60 5/6	g: 30-45 6/7	g: 5-30 7/6			
g: 60-120 4/5	g: 45-60 5/6	g: 30-45 6/7	g: 5-30 7/6			
g: 60-120 4/5	g: 45-60 5/6	g: 30-45 6/7	g: 5-30 7/6	7	7	7

4. **Soil Moisture Regime** is an integration of all the variations in soil moisture supply throughout the complete vegetation cycle. The moisture regime classes are inferred from the pore pattern and depth of the mineral soil material, the topographic position of the site and characteristics of the soil profile such as mottling or grey gley horizons which indicate impeded drainage.

Soil Drainage is the rapidity and extent of removal of water from soils in relation to additions

4/5 most probably drainage class(es), the dominant drainage class is shown in the first position

1 very rapid
2 rapid
3 well
4 mod well
5 imperfect
6 poor
7 very poor

5. Of > 60 cm or Om Oh > 40 cm

SYMBOLS

O organic horizons developed mainly from mosses, rushes and woody material (numbers indicate depth of 'O')

Of (fibric) the least decomposed organic horizon containing large amounts of well preserved fibre

Om (mesic) an intermediately decomposed organic horizon with properties intermediate to an Of and Oh horizon

Oh (humic) the most decomposed horizon containing only small amounts of well preserved fibre and the major amount of material at an advanced stage of decomposition

Table A 2. Soil moisture regime for mineral soils with permafrost[1]

Pore pattern of mineral soil materials		Soil moisture regime[2]									
Perviousness class	**Pore pattern class**	**Dry**	**Moderately dry**	**Moderately fresh**	**Fresh**	**Very fresh**	**Moderately moist**	**Moist**	**Very moist**	**Moderately wet**	**Wet**
Rapid	Extremely open	A = > 1 m	A = 60-100					A = 20-60			A = 0-20
Rapid	Very open		A = > 1 m A = 60-100 No G to frost	A = 60-100 G > 60	A = 60-100 G = 45-60	A = 60-100 G = 20-45	A = 60-100 G = 0-20		A = 20-60		A = 0-20
Rapid	Open		A = > 1 m A = 60-100 No G to frost	A = 60-100 G > 60	A = 60-100 G = 60-45	A = 60-100 G = 20-45	A = 60-100 G = 0-20		A = 20-60		A = 0-20
Rapid	Moderately open			A = > 1 m	A = 60-100 No G to frost	A = 60-100 G > 60	A = 60-100 G = 45-60	A = 60-100 G = 20-45	A = 60-100 G = 0-20	A = 20-60	A = 0-20
Moderate	Moderately retentive			A = > 1 m	A = 60-100 No G to frost	A = 60-100 G > 60	A = 60-100 G = 45-60	A = 60-100 G = 20-45	A = 60-100 G = 0-20	A = 20-60	A = 0-20
Moderate	Retentive			A = > 1 m	A = 60-100 No G to frost	A = 60-100 G > 60	A = 60-100 G = 45-60	A = 60-100 G = 20-45	A = 60-100 G = 0-20	A = 20-60	A = 0-20
Moderate	Very retentive			A = > 1 m	A = 60-100 No G to frost	A = 60-100 G > 60	A = 60-100 G = 45-60	A = 60-100 G = 20-45	A = 60-100 G = 0-20	A = 20-60	A = 0-20
Slow	Moderate restricted			A = > 1 m	A = 60-100 No G to frost	A = 60-100 G > 60	A = 60-100 G = 45-60	A = 60-100 G = 20-45	A = 60-100 G = 0-20	A = 20-60	A = 0-20

[1] According to Brown and Kupsch (1974), permafrost occurs where the thermal condition in soil or rock of having temperatures below 0°C persist over at least two consecutive winters and the intervening summer. The active layer (A) (also depth of thaw, seasonal frost, seasonally frozen ground, seasonally thawed ground) is the top layer of ground above the permafrost table that thaws each summer and freezes each fall. In the present case, the active layer was determined by measuring the depth to permafrost in September of 1978.

[2] G = Gleying- for explanations see Bates *et al.* 1982. (preceeding table of pore pattern soil moisture regime for deep mineral soils.)

Appendix B

Diagrams of Relationships Between Forest Types

The surveyed forest types were subjected to various analyses based on data relating to environmental factors, trees, soils, plants, and tree growth. The analyses explored the environmental factors to better understand the overall nature of the types and the relationships between them.

For the benefit of those statistically inclined, in each diagram (Figures B1 to B5) different environmental characteristics have been mapped. The positions of the plotted forest types are based on the component scores on two axes from a principal components analysis (Pielou 1984) of the characteristic species in Orlóci and Stanek (1979). For more on the basic method of principal component analysis and programs see Orlóci (1978), Orlóci and Kenkel (1985), and Wildi and Orlóci (1983). The nature of the method is to reduce the dimensionality of the data from, in this case, many species to two axes. The axes themselves do not, therefore, bear any direct one-to-one relationship with any of the original species. They are mathematical abstractions which represent a composite of species which tend to co-occur.

Various characteristics of the forest types have been superimposed on the same scatter diagram so that comparisons can be made. The characteristics include soil drainage (Figure B1), depth to permafrost (Figure B2), maximum depth of soil organic matter (Figure B3), canopy tree species (Figure B4), and soil orders (Figure B5).

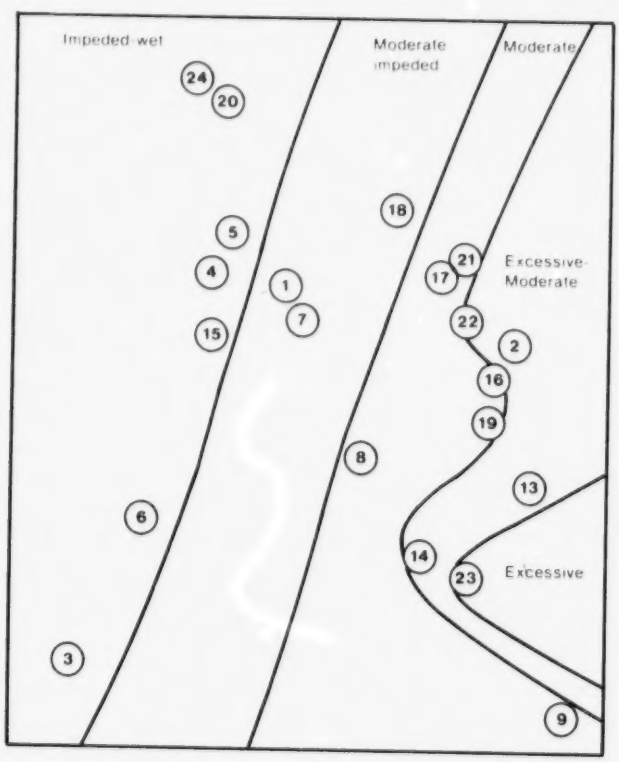


Figure B1. Scatter diagram of forest types and contours of drainage classes according to Bates et al. (1982).

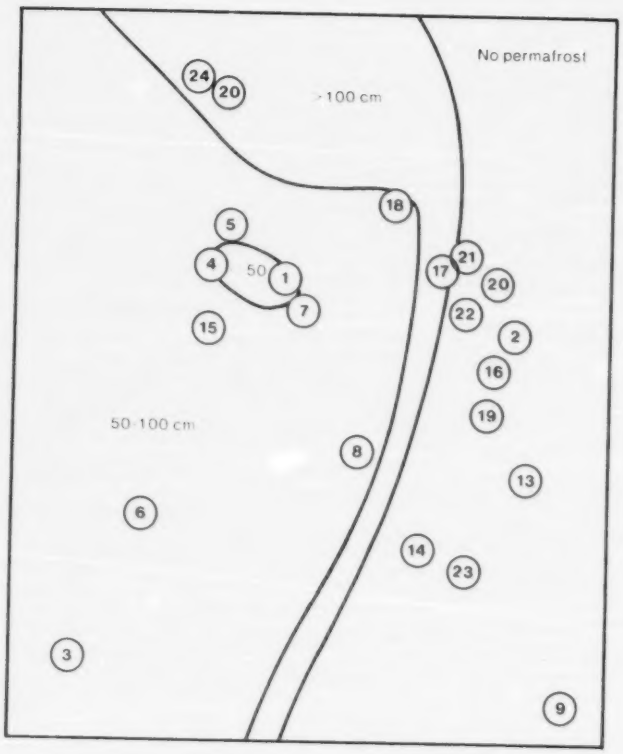


Figure B2. Scatter diagram of forest types and contours of depth to permafrost.

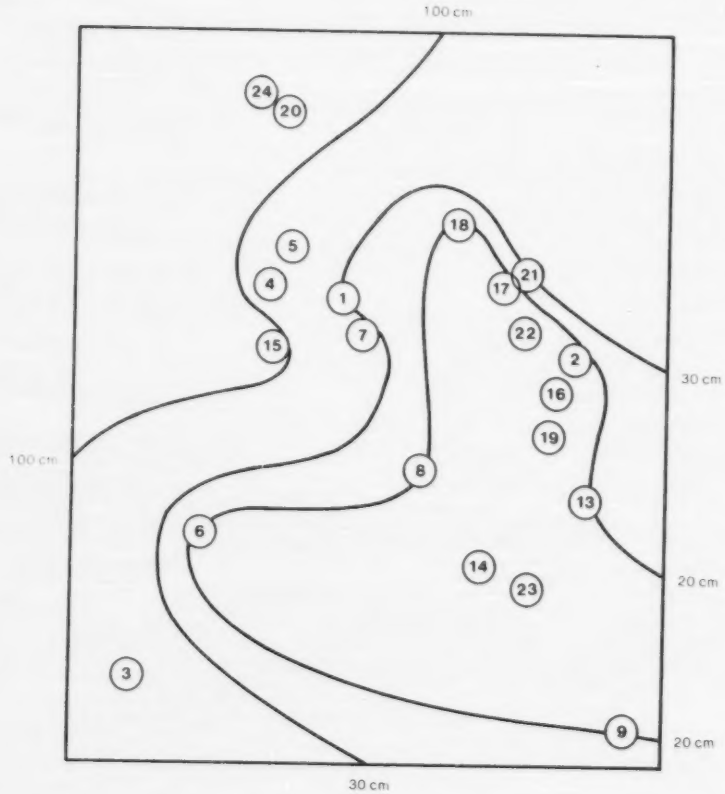


Figure B3. Scatter diagram of forest types and contours of organic matter depth.

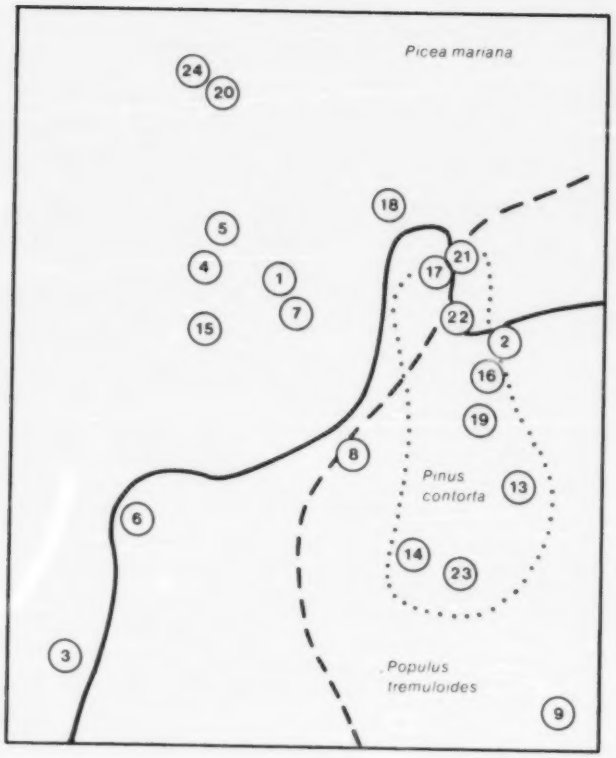


Figure B4. Scatter diagram of forest types and limits of major tree species.

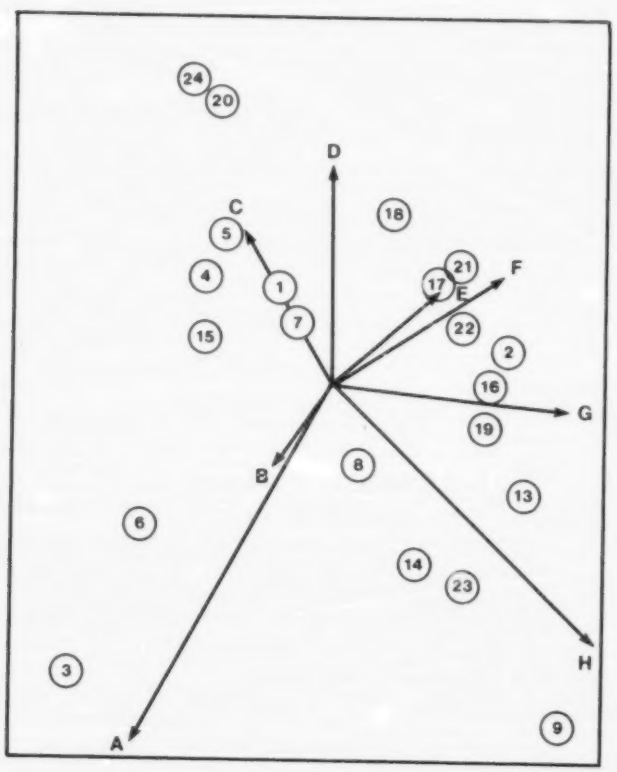


Figure B5. Scatter diagram of forest types and the contours of soil order distribution.

Appendix C

Illustrations of Plant Indicator Species.

The plants included in this section are those used in the key to operational groups and in the forest types given as examples of operational groups.

When faced with an unknown plant, examine it carefully and note features such as the size, habit, color, hairiness (pubescens), flower and fruit characteristics, bark, and the arrangement as well as the shape and attachment of leaves. Note that certain features such as height, leaf size and color may vary somewhat depending on the season, microclimate and other environmental influences. Other characters such as general form, flower and fruit type, and leaf arrangement do not vary.

Decide which group the plant belongs to and examine the line drawings to find which one best matches your specimen. When a possible identification is made, carefully study the text and compare each feature described with those displayed by the unknown plant. If your plant does not fit the drawings or descriptions it is probably a species not included in the guide.

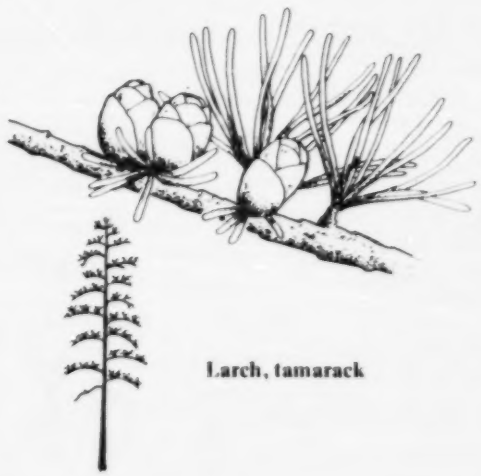
Paper birch

Trees

Betula papyrifera Marsh.

Paper birch

These trees are commonly 5 to 20 m tall with exfoliating bark (creamy white to reddish, marked with elongate, horizontal leticels). The twigs are puberulent to glabrous and bear yellowish to whitish resin glands. The leaves are ovate to lance-ovate, often acuminate and sharply serrated with a dull green coloring above and a paler green with soft down below.

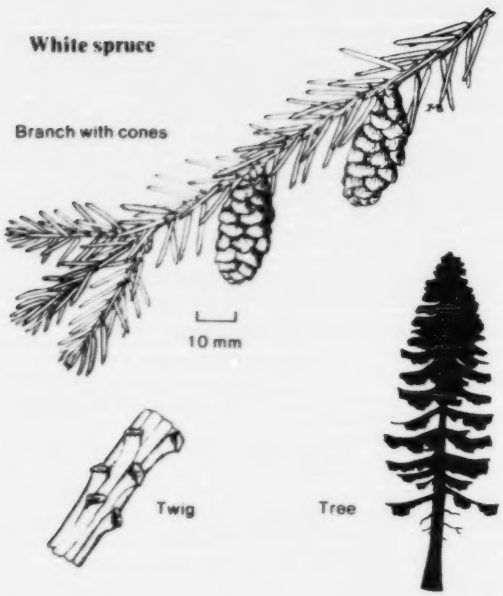


Larch, tamarack

Larix laricina (Du Roi) K. Koch

Larch, Tamarack

In the Yukon, these trees are rarely more than 10,m tall. The leaves are 10 to 25 mm, soft, needle shaped and arranged on dwarf shoots in clusters which are shed each autumn. This tree flowers in the spring, with cylindrical staminate flowers and ovulate pistillate flowers which curve upward and mature in one season. The cone is persistent and seed release is from September on. This is a pioneer species which is shade intolerant and occupies wet sites to escape competition; it prefers seepage sites to those with stagnating water.



Picea glauca (Moench) Voss

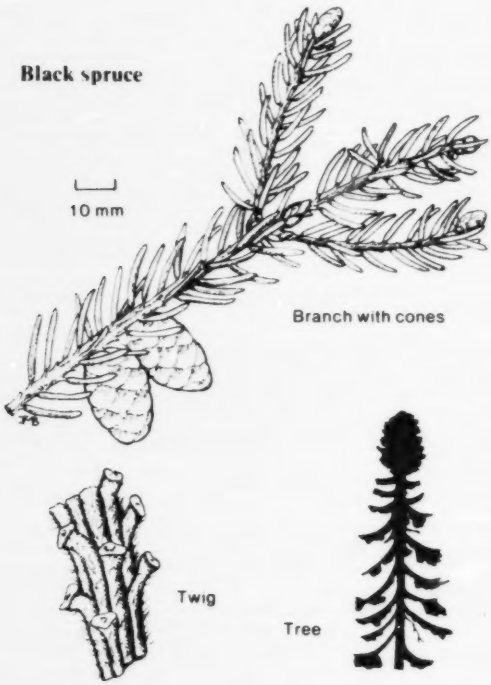
White spruce

White spruce is a forest tree adapted to a wide range of sites. It can be identified by its usually uniform conical crown and spreading, drooping branches. The trunk is straight with a pronounced taper. The bark is thin, scaly, light greyish brown and the inner bark is silvery white. The twigs are whitish grey to yellowish, hairless and covered with persistent short pegs after the leaves are lost. The needles are broad with blunt ends, up to 2 cm long, straight, four-sided, rather spreading, green or bluish green, often with a white bloom. The cones are slender and cylindrical. Seed dispersal starts from August to November depending on cone ripening. The scales are stiff, smooth, indented, close fitting, brownish, opening almost to a right angle and easily crushed. Found in treed bog-like taiga as well as in the best mixed stands, white spruce is shade tolerant and successfully competes with *Picea mariana*. It grows best on fresh to moist, nutrient rich soils.

Picea mariana (Mill.) B.S.P.

Black Spruce

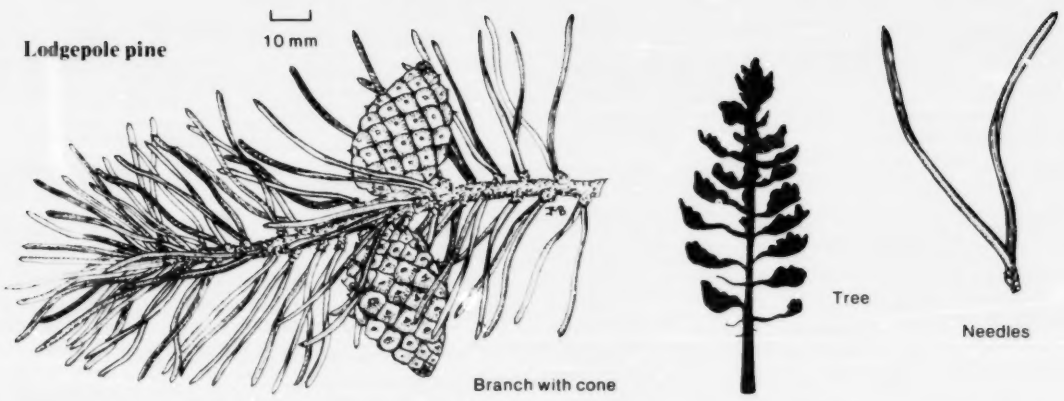
In the Yukon, this tree usually grows in a treed bog-like taiga or mixed coniferous stands. Its crown is rather narrow, often with a compact club-like top. The branches droop with upturned ends and those touching the ground often layer and form new plants. The trunk has rather sparse branches for much of its length. The bark is thin, scaly dark greyish brown and the inner bark is a rich olive green. The twigs are dark brown and covered with short, dense hairs. The leaf pegs are long and prominent. The needles are broad, about 1.5 cm long, stiff, blunt, four-sided, dark bluish-green and rather dull. The cones are short and egg-shaped, almost spherical when open. Seed dispersal is from October and seeds remain active for several years. The scales are close-fitting, toothed, purplish to dark brown, and only slightly spreading when open; they are firm and not easily crushed. Black spruce is common on wet sites and occurs also on sandy, usually moist and acidic soils. It is shade intolerant. In the Yukon it is often found on permafrost less than 60 cm deep.



Pinus contorta Dougl.

Lodgepole pine

This is a slender tree with a straight trunk and rather bent and twisted branches. Its bark is orange brown to grey, thin and flaky. The twigs are orange, reddish brown to nearly black and the buds are reddish brown and resinous. Lodgepole pine needles generally develop in twos with a persistent sheath, they are dark green to yellowish green, stiff and often spirally twisted. It has closed cones which are less than 6 cm long, pointed egg-shaped, usually asymmetric and stalkless. Seed release takes place in the fall for several years, but only during dry, hot weather or after a fire. The scales are thickened at the tips and bear curved prickles

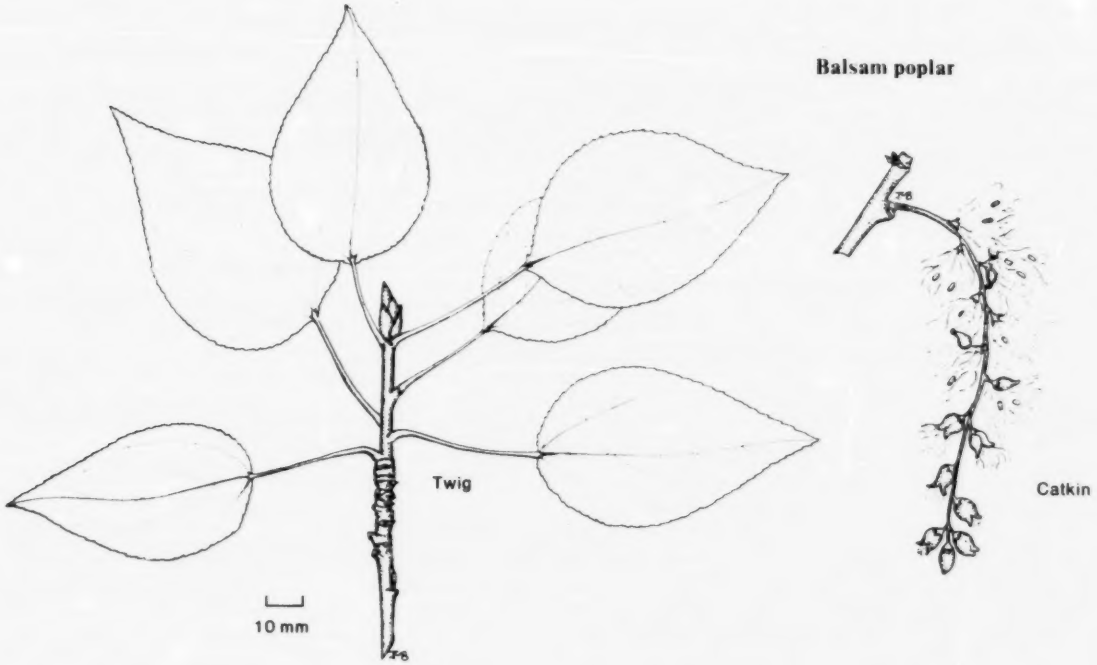


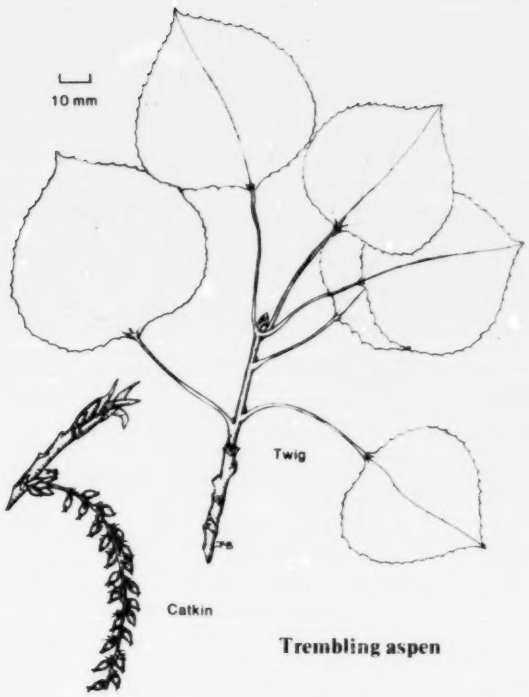
which are sometimes shed. It is a pioneer species, intolerant of suppression and it occupies a wide range of sites, commonly after fire. Initially, it is a fast-growing tree which slows down after about 50 years.

Populus balsamifera L.

Balsam poplar

This tree generally grows up to about 15 m tall but will occasionally grow much taller. The trunk is slender and cylindrical and it has a narrow, open crown. Its bark is smooth and greenish brown, and becomes furrowed into flat ridges and v-shaped crevices with age. The twigs are stout, smooth and reddish brown. The buds are slender, long-pointed, very resinous and sticky, reddish brown and fragrant. There are lateral buds pressed against the twig. The leaves are egg-shaped, gradually tapering to a sharp tip, rounded at the base, mostly hairless and finely toothed with many low rounded teeth which turn upwards at their tips. The upper surface is dark green and the lower surface is whitish green and often stained with blotches of brownish resin. The leaf stalk is slender, round in cross section and often bears glands just below the blade. The fruit is egg-shaped, consisting of hairless pods, loosely arranged in a catkin. Balsam poplar is a pioneer species intolerant of shade. Its best growth is achieved on fresh to moist, nutrient-rich soils, and also near rivers, lakes and seepage sites. Balsam poplar has a shallow root system and propagates chiefly by root suckers.





Trembling aspen

Populus tremuloides Michx.

Trembling aspen

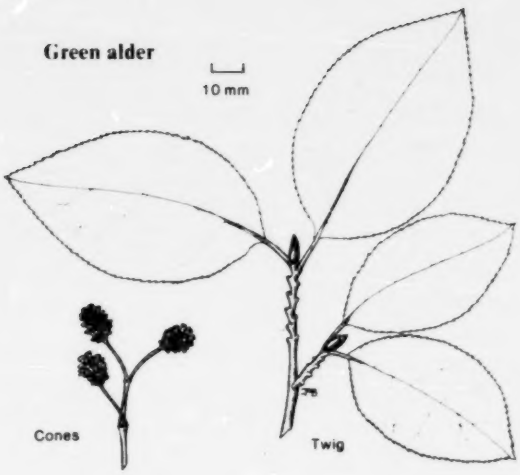
Trembling aspen is a slender, graceful tree found on almost all soils. The bark is smooth and rather waxy, pale green to almost white, and sometimes becomes roughened into long flat ridges with age. Its twigs are slender, shiny and brownish grey. The buds are reddish brown, conical, hairless and are not sticky or fragrant. The lateral buds are slightly curved. The leaves are nearly circular, abruptly sharp-pointed at the tip, flat, rounded or heart-shaped at the base, deep green above and paler below. The leaf stalk is flattened, slender and usually longer than the blade. The fruits are small, hairless, conical pods arranged in a slender catkin. This is a pioneer species intolerant of shade. It propagates chiefly by root suckers and occupies even the poorest soils.

Shrubs

Alnus crispa (Ait.) Pursh.

Green alder

Green alder is a bushy upright shrub sometimes reaching 3 m in height with greyish brown bark. The twigs and branches are rather glandular and sticky



when young and hairless. The leaves are alternate and are egg-shaped to broadly elliptic with an acute tip and a rounded base; the leaf margins are finely and irregularly double-toothed with the teeth sharp and pointed. The male catkins are grouped in long-stalked clusters which elongate in May and June as the leaves expand. The female catkins are smaller. Green alder fruits are small, dark, oval wooden cones on long stalks. Green alder is usually found near streams and sites with telluric water. The roots carry nodules with nitrogen-fixing bacteria. This shrub appears intolerant of stagnating water.

Alnus incana (L.) Moench

Grey alder, mountain alder

This is a large shrub or small tree with greyish to brownish bark. The young twigs appear slightly velvety

Grey alder, mountain alder

and are often glandular. The leaves are oval or egg-shaped and irregularly double-toothed to shallow-lobed. The venation is ladder-like and the leaf stalks are slender. The catkins appear in the early spring before the leaves open. The cones are oval, dark brown, woody and short-stalked.

Betula glandulosa Michx.

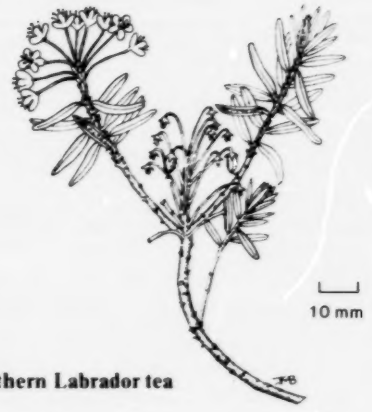
Dwarf birch

Usually less than 1 m tall, dwarf birch is a low shrub with grey or brownish bark. The twigs are hairless and liberally covered with yellowish, sticky, wart-like glands. The leaves are oval or roundish, green on both surfaces, sticky-glandular beneath and irregularly toothed. The teeth are rounded and sometimes double toothed. The fruiting catkins are about 1.5 cm long, upright and on short stalks. Dwarf birch grows in bog-like taiga, shrub tundra and peatlands.

Ledum groenlandicum Oeder

Labrador tea

This is an erect or spreading shrub up to 1.5 m high. The twigs are covered with reddish wooly hairs and the leaves are oblong to linear oblong, blunt, strongly to slightly rolled under at the edges and reddish wooly beneath (or white wooly when young). The flowers are creamy white, in clusters with few to many flowers. The flower stalks are rough and covered with short white hairs. The fruit consists of dry capsules on arching stalks. Labrador tea generally inhabits hillsides with a tendency toward moist, cool, and acidic soil conditions.



Ledum palustre ssp. *decumbens* (Ait.) Hulten

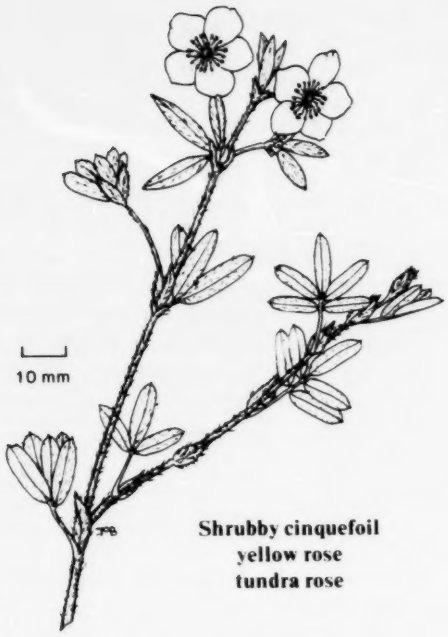
Northern Labrador tea

Northern Labrador tea is a low spreading shrub up to 0.5 m long. The twigs and branches are covered with reddish, wooly hairs, and the leaves are linear or very narrow oblong, dark green and leathery, strongly rolled in at the edges and reddish wooly beneath. The flowers are creamy white and occur in clusters which may contain several or many flowers, and have a spicy smell. The flower stalks are covered with contorted reddish hair. The fruit consists of dry capsules on a stalk abruptly bent near the top. This shrub occurs often on sites with acidic soil and a shallow active layer.

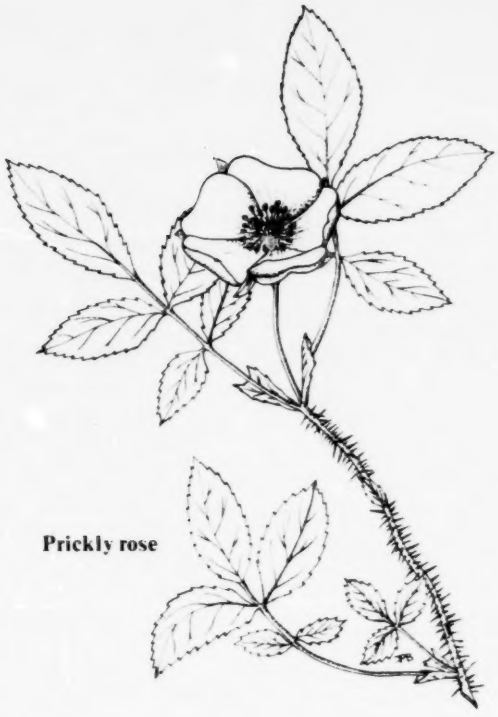
Potentilla fruticosa L.

Shrubby cinquefoil, yellow rose, tundra rose

This is a much-branched shrub up to 1.5 m tall, but it is often lower. Its bark is reddish brown, with a membranous and shredding sheath. The leaves come



Shrubby cinquefoil
yellow rose
tundra rose



Prickly rose

with three to five leaflets, growing in groups at the ends of branches. All the leaflets are narrow oblong or elliptic and grey silky on both surfaces. The flowers yellow blooms are showy, 2 to 3 cm in diameter and grow singly or in groups of a few in leaf axils at the top of stems. There are many seeds, which are beaked and covered with long, white, silky hairs. This shrub prefers cold regions on calcareous substrate and unshaded locations.

Rosa acicularis

Prickly Rose

Prickly rose is a bushy shrub developing up to 1 m tall. The branches are reddish and densely covered with straight, slender thorns. The leaves alternate and are divided into three to seven (usually five) sharply toothed, oval or egg-shaped leaflets. The flowers are large, deep pink and usually solitary at the ends of leafy branches.

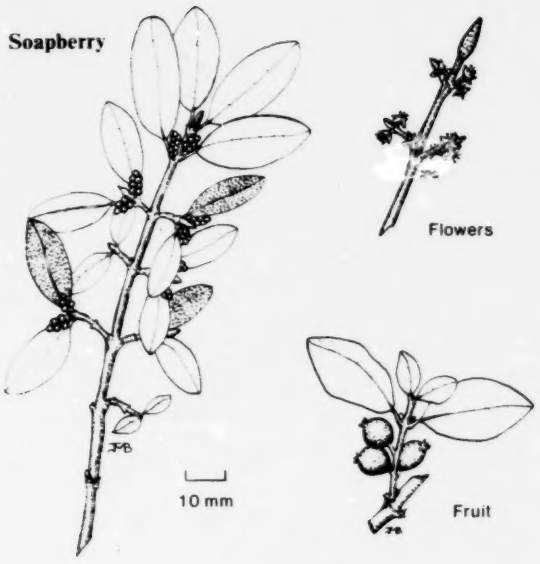
Willows

Salix species

Willows

These are shrubs or small trees which are either upright or sprawling; sometimes they have several stems. The leaves are elliptic to lance-shaped and are often hairy, especially beneath or when young. The leaf margins are plain, wavy or toothed. The flowers come in catkins which appear before or with the leaves and may reach 7.5 cm in length.

Willows are a group of variable species which are difficult to tell apart.



Shepherdia canadensis (L.) Nutt.

Soapberry

Soapberry is an erect and ascending shrub which is 1 to 2 m tall with brown, scaly branches. Its leaves are egg-shaped to lance-shaped, rounded at both ends, green above and brown scaly beneath, with sparse silvery hairs on both surfaces. The flowers are brownish green with four thick petals which open in May before the leaves have emerged. The fruit is a bitter, juicy, red drupe, which ripens in mid summer. Soapberry is found on calcareous substrate and prefers openings.

Vaccinium uliginosum L.

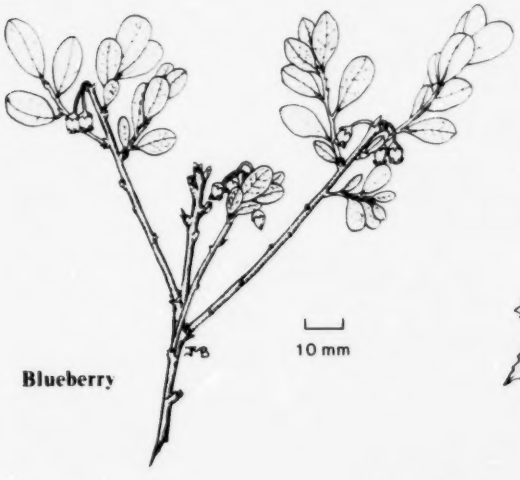
Blueberry

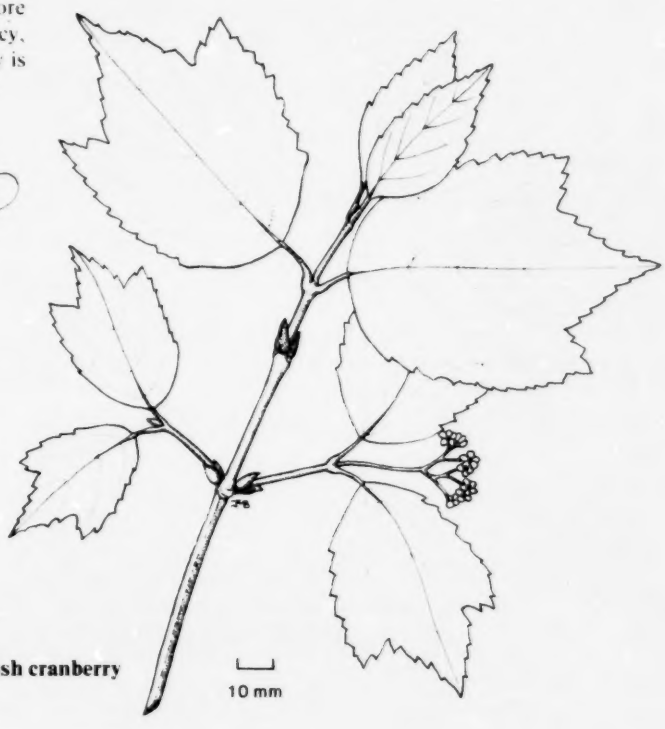
Blueberry is a low, multi-branched shrub, which can be either depressed or erect and up to 1 m tall. The twigs and small branches are finely velvety. Blueberry leaves are deciduous, small, oval, firm and somewhat leathery, dull green above and pale or whitish beneath. The leaf margins are untoothed. The flowers are pink, urn-shaped on long stalks with one to many growing from scaly buds of the previous year. The fruit are blue to black berries with a whitish bloom and are edible. Blueberry is common in organic terrain, tundra and on the summits of mountains.

Viburnum edule (Michx.) Raf.

Highbush cranberry

This erect or straggling shrub grows up to 2 m tall. Its twigs are smooth, purplish brown, and are often angled with longitudinal ridges. The leaves are opposite, egg-shaped to three-lobed, sharp pointed at the tip, rounded, and are tapered or heart-shaped at the base. The upper leaf surface is dark green; the lower surface is paler and hairy along the veins. The leaf margins are coarsely toothed. Sometimes several stalked glands may be present where the leaf stalks join the leaf blade. The flowers are creamy white in small,





open, few-flowered clusters, and are usually situated on short two-leaved branches which blossom in late June and July. The fruit is an egg-shaped berry-like drupe; it is yellow at first and then turns orangy red with large and flat pits. This plant is found in moist, shady locations of the boreal region; in the subarctic and at higher elevations it prefers openings.

Dwarf Shrubs

Arctostaphylos uva ursi (L.) Spreng.

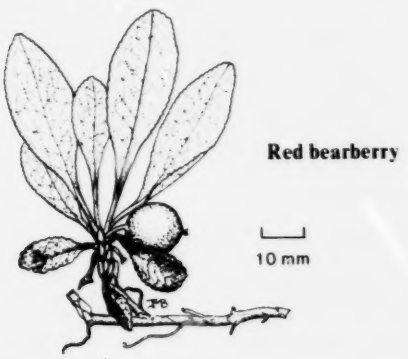
Common bearberry

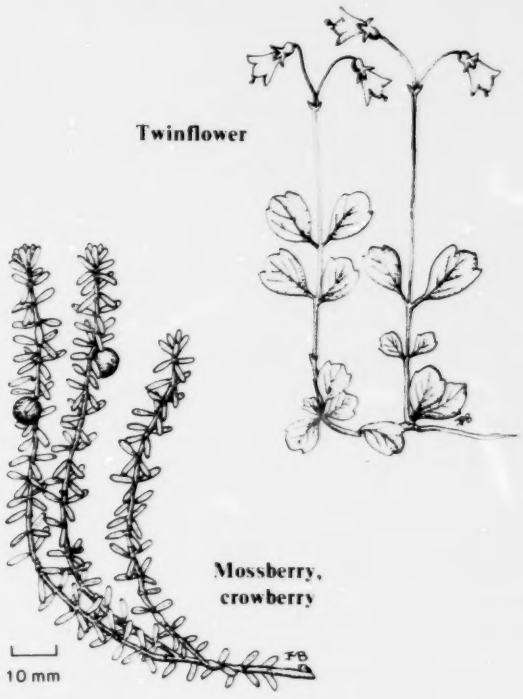
This is a prostrate, multi-branched shrub with trailing stems and ascending branches. The bark is reddish to dark grey. The leaves are egg-shaped to lance-shaped, untoothed, leathery, evergreen, and rather shiny on the upper surface; they grow all along the stem, but more densely near the tips. The leaf stalk is short. The flowers are white or pink, tinged with deep pink and grow in dense, few-flowered clusters at the tips of branches. The fruit is dull, dark red, rather dry and mealy. Common bearberry is found on sites with siliceous soil material and is adapted to droughty conditions.

Arctostaphylos rubra (Rehd. and Wils.) Fern

Red bearberry

This is a low-growing, mat-forming shrub with brown, shredding bark. The leaves are egg-shaped with crinkled edges, somewhat leathery, and much veined; they turn bright red in the autumn. The remains of the previous year's leaves persist beneath the rosette-like growth of the current year. The leaf stalks are usually well developed. The flowers are small and yellowish green, and appear in clusters at the ends of branches early in the year before the leaves have opened. The fruit is bright red and very juicy. In the subarctic red alpine bearberry has adapted to droughty conditions and is found together with *Rhododendron lapponicum* on permafrost. It is often found in calcareous soils and poorly drained sites.





Empetrum nigrum L.

Mossberry, crowberry

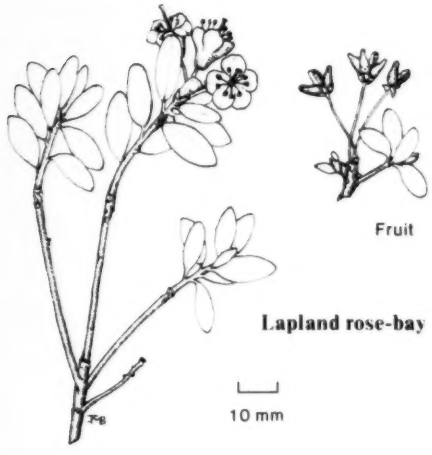
This is a low, freely branching, depressed, matted, evergreen shrub with ascending branches reaching 0.5 m in height. The leaves are small (5 mm), alternate or whorled, linear to oblong, and spreading. The flowers are dark purple, inconspicuous, and grow singly in the leaf axils. The fruit is purplish black, shiny, juicy and sweet. This shrub is found generally in the subarctic.

Linnaea borealis

Twinflower

Twinflower is a small, low, trailing plant often half hidden among other vegetation and litter. The leaves

develop in pairs along the stem and are nearly round, but bluntly toothed with short stalks. The flowers are pink, funnel-shaped, and in nodding pairs on an erect slender stalk; they bloom in the summer. The fruit is a single seed enclosed by the sepals.



Rhododendron laponicum (L.) Wahl.

Lapland rose-bay

This is a multi-branched shrub up to 1 m tall with prostrate or ascending branches. The twigs are rather scurfy, and the leaves are elliptic to lance-shaped, obtuse at the tip, curled under slightly at the edges, scurfy and glandular on both surfaces, but especially beneath and are evergreen or falling late. The leaf stalks are short. The flowers are pink, rather showy and found in clusters of two to four at the tips of branches. The flower stalks are short at first, but lengthening as the fruits ripen. The fruit is composed of dry, scurfy capsules. Lapland rose bay is a shrub inhabiting circumboreal arctic-montane regions and is found on sites with a shallow active layer.

Vaccinium vitis-idaea L.

Mountain cranberry

Mountain cranberry is a small woody, subterranean plant, emitting decumbent ascending stems up to 25 cm tall. Its leaves are persistant, leathery, obovate, and have brownish glands on the lower surface. The corolla are campanulate, have four or five lobes and have inferior ovaries. The berries are red, sour and edible.

This species is characteristic of arctic, subarctic and montane regions. It prefers open woods, thickets and tundra.

Mountain cranberry

Grasses

Calamagrostis purpurascens R. Br. in Richards

Purple reedgrass

This is a coarse, strongly tufted, often short rhizomatous grass up to 1 m tall. The stems are stiff, smooth or rough-hairy. The leaves are flat or inrolled at the edges, bluish and much shorter than the flowering stems. The flowering panicles are narrowly pyramidal and dense to loose. The spikelets are small, numerous and purplish bronze. It is found on wet alluvium.

Eriophorum vaginatum L.

Tussock cotton grass

This is a grass-like plant forming large compact tussocks. The old basal sheaths persist for several years, and the stems are smooth, and rounded-triangular. The leaves are narrow, channelled and become smaller up the stem. The sheaths are expanded at the top. The uppermost leaf sheath, at about the middle of the stem, is bladeless. The spike is single, forming at maturity a globular head of fine, silky, white "cotton." The scales are pale and margined. This plant is found in the subarctic in bog-like tundra and in wet sites; it tolerates a shallow active layer.

Festuca altaica Trin.

Altai fescue

Altai fescue is a densely tufted grass forming large, firm tussocks. Its old sheath and leaf bases persist for many years. The leaf blades are coarse, inrolled with rough margins, often folded, and sometimes very narrow. The flowering stem is erect and can grow up to

1 m in height, although it is usually about half of this. The flowering panicle is lax and open with spreading branches which droop with age. The spikelets are greenish or purplish bronze. Altai fescue is a species of cold regions with dry soils and is somewhat xerophytic.

Sedges

Carex aquatilis Wahl.

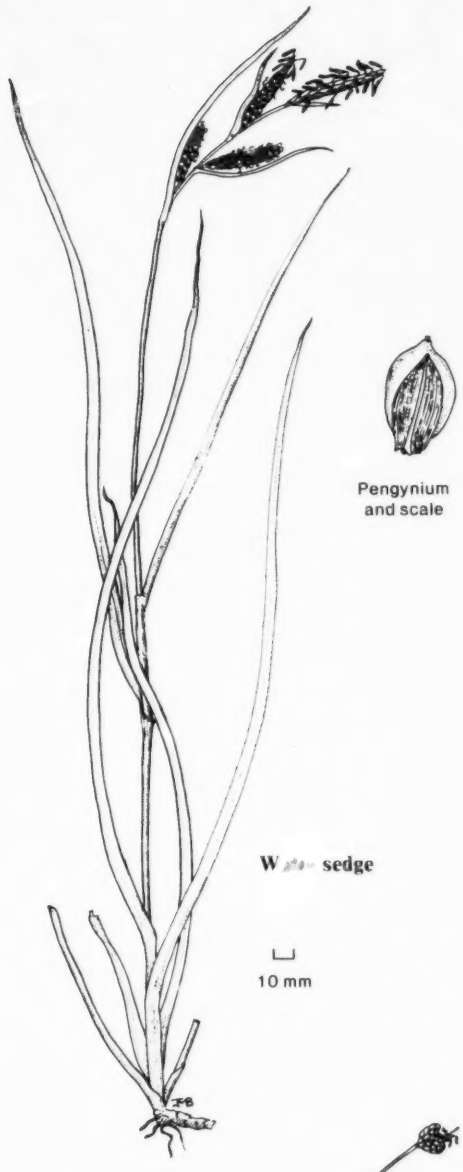
Water sedge

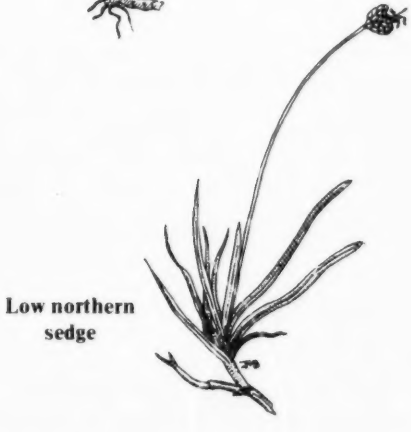
Water sedge is a tall, leafy, rhizomatous sedge forming dense tufts with several sterile shoots surrounding a fertile one. The rhizomes are stout, scaly and yellowish to brown. The sheaths at the base of the plant are mostly reddish to purplish black. Its leaves are glaucous, channelled or flat and become longer up the stem, and those on sterile shoots are almost as long as the flowering stalks. The spikes are stalkless, erect or nodding, the terminal ones are male and the lowest are female. The perigynia are pale green, rather flattened and roundish to egg-shaped with a tiny beak. The narrow egg-shaped scales are about equal to the perigynia and are blackish with a green center. The black and green contrast on the female spike is often a striking feature of this species. Water sedge is generally found on wet sites.

Carex concinna R. Br.

Low northern sedge

This is a small, tufted sedge with a widely creeping, slender, dark brown rhizome. The sheaths at the





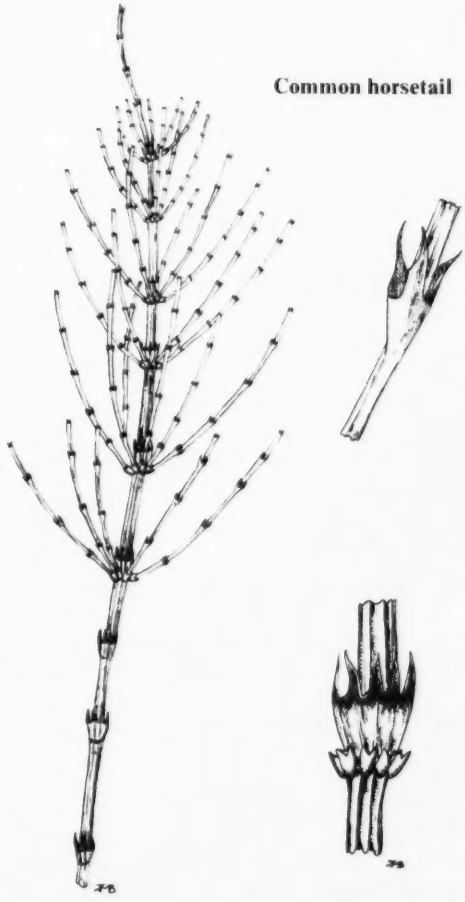
base of the shoot are straw-colored to brown, and sometimes colorless. The leaves are flat, often somewhat curved and grow in bunches from the rhizome. The flower stems are slender and arching, leafless, and up to 15 cm tall. The spikes are very crowded at the stem tip and the terminal one is male. The perigynia are three-sided, pale gray and hairy. The scales are egg-shaped and are brown with a pale center; the margins are shorter than the perigynia. This grass if found in cold regions, and in open forests and rocky sites.

Horsetails

Equisetum arvense L.

Common horsetail

Common horsetail is composed of sterile green stems which are ridged and jointed. Its branches are formed in whorls and are rather stiff, unbranched, jointed, and solid with large, loose sheaths. The

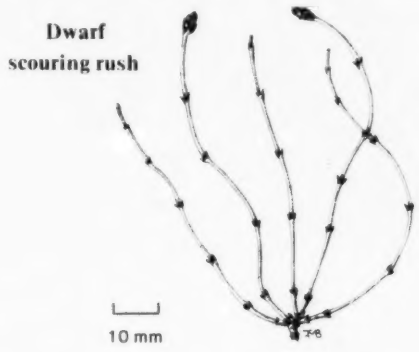


sheaths of the stem joints have dark, large, triangular teeth. The teeth of the branch sheaths are lance-shaped with long, fine points. The fertile stems appear in early spring. They are short-lived, unbranched, whitish, pinkish or brownish (not green) and topped by an oval cone.

Equisetum palustre L.

Marsh horsetail

Marsh horsetail stems are erect, about 20 cm tall, jointed, green, branched or unbranched, deeply ridged, and have a small central cavity. The sheath of the joints becomes larger up the stem. The teeth of the branch sheaths number about 10 or fewer and are long and black with conspicuous pale margins. The fertile and sterile stems are similar. Marsh horsetail is found in wet sites with moving water and it tolerates permafrost.



Equisetum scirpoides Michx.

Dwarf scouring rush

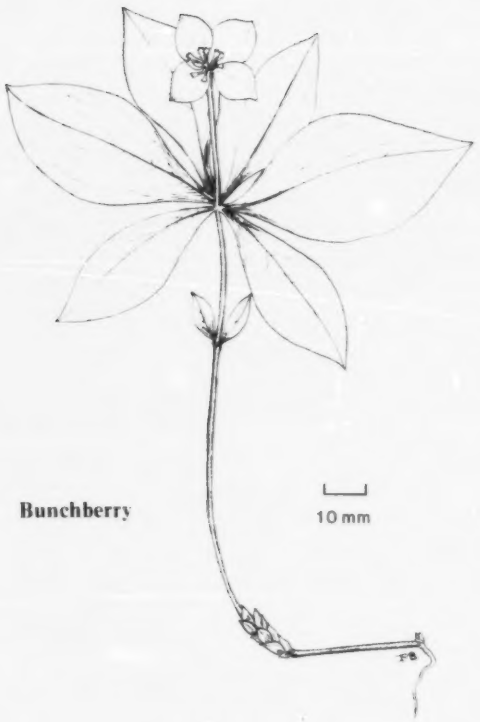
This is a small matted plant with many twisted, unbranched, jointed stems often entwined with other vegetation. The sheaths covering the stem joints are small, dark, few-toothed, and the teeth are delta-shaped. The fertile and sterile stems are similar. It is found in temperate regions on seepage sites together with hydrophile mosses and in the subarctic on gleyed cryosols.

Herbs

Cornus canadensis L.

Bunchberry

Bunchberry is an erect herb about 15 cm tall from a creeping rhizome. The leaves are stalkless; the lowest are the smallest. They are scale-like and in pairs. The upper leaves are in a whorl of four to six; they are egg-shaped, pointed at both ends and conspicuously veined. The flowers are tiny, yellowish, in a tight cluster, and surrounded by four white, petal-like bracts. The fruit consists of orange-red berries growing in a tight bunch. It is found in coniferous forests together with feather mosses (*Hyphnum, Pleurozium, Hylocomium*).



Epilobium angustifolium L. sensu lato

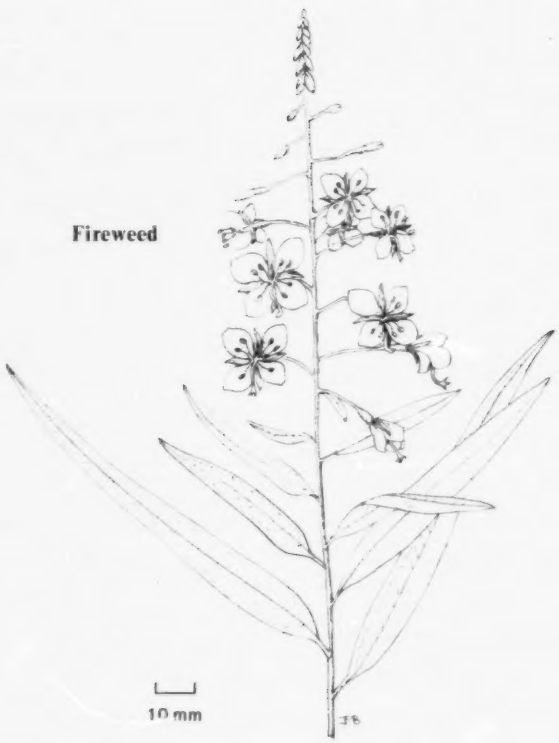
Fireweed

Fireweed is a plant growing up to 1 m tall from freely budding, spreading, branched rhizome-like roots. The stem is often purplish and usually unbranched. The leaves are alternate, thin, lance-shaped, green, conspicuously veined, more or less stalkless and crowded up the stem. The flowers are showy, in a dense raceme and bloom in late summer. There are four petals which are colored pink or purplish and sometimes white. The capsules open to release many seeds with tufts of long, dingy-white, silky bristles. Fireweed favors pioneer-clearings and burns, and is intolerant of shade.

Lupinus arcticus Wats.

Arctic lupine

This is a tufted, almost bushy plant with one to a few ascending stems up to 0.5 m tall. It has numerous leaves which are mostly basal and palmately divided into oblong leaflets colored dark green. The leaf stalks are long and slender, and the flowers are showy with bluish purple coloring and borne in a dense spike-like raceme. The fruit are oblong, flattened, hairy pods which become strongly twisted when open. In general,



Arctic lupine is found in openings and open deciduous forests; it ameliorates through nitrogen fixation.

Mertensia paniculata (Ait.) G. Don

Tall bluebells

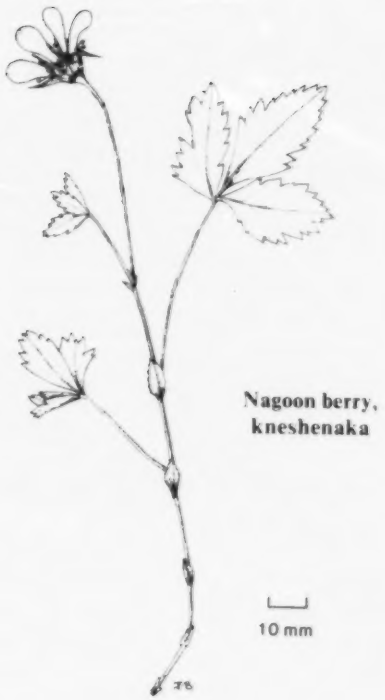
This is a robust herb which grows up to 0.5 m tall or more. It stems are erect or sprawling, growing from a stout taproot. The leaves are rough and hairy. The basal leaves are egg-shaped to elliptic, often long-pointed, dark green and taper to a long stalk. The stem leaves are progressively smaller towards the top and are short-stalked or stalkless. The flowers are bell-shaped, nodding, and pink in bud, but soon turning blue; they are borne in a dense or open-branched inflorescence.

Tall bluebells

Rubus arcticus L.

Nagoon berry, kneshenaka

These are tufted plants with a branching, rather woody base. The stems are slender with one or two leaves. The leaves are divided onto three egg-shaped, irregularly toothed leaflets. The flowers are single,



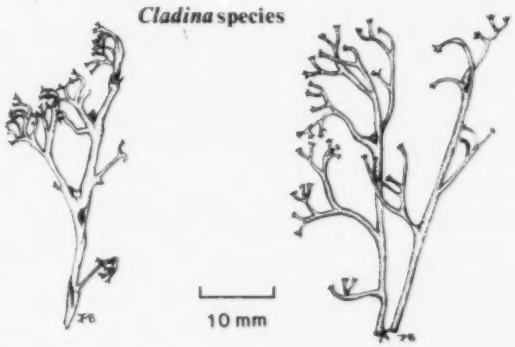
Nagoon berry, kneshenaka

showy and dark pink to purple. The fruit is a red, sweet, juicy raspberry. This is a common arctic bramble.

Lichens

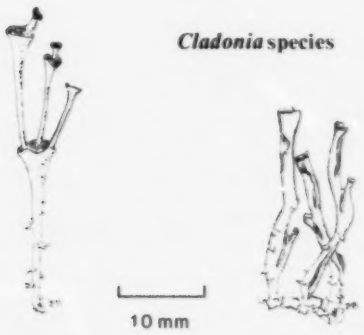
Cladina species

Cladina is a greyish or greenish lichen growing in tangled colonies which are often extensive. The main stem is round in cross section, distinct and sometimes forms discrete coral-like heads. The branches are



Cladina species

much-branched, and the ultimate branches are grouped in threes or fours and often all tend to point in the same direction. *Cladina* is common on moist organic matter.



***Cladonia* species**

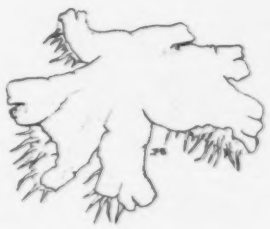
Cladonia species

Cladonia is a greyish upright lichen usually growing in small patches. The body is often topped with a shallow cup which may proliferate to form stacked units. Dark brown or red fruiting bodies are often present on the upper cup margins. It is very variable and common on somewhat dry organic and mineral substrate. It is tolerant of drought.

Peltigera aphthosa

Peltigera aphthosa (L.) Willd.

This lichen, with large, wide, flat lobes, grows loosely over mosses and other lichens. The upper side of the lobes are a pale greeny grey when dry and dark olive green when wet, with dark green warty dots scattered over the surface. The underside of the lobes are a dirty greyish brown and dirty white towards the edges with rather inconspicuous pale veins. It is quite common.

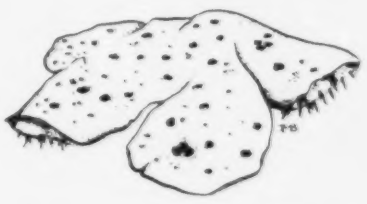


Dog lichen

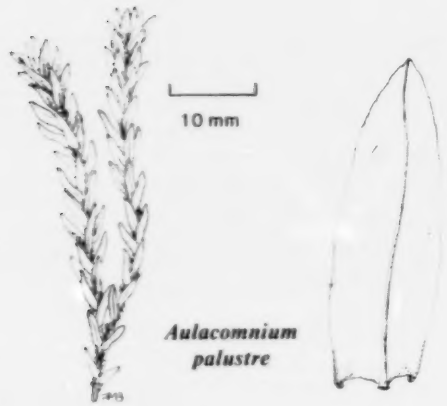
Peltigera canina (L.) Willd.

Dog lichen

Dog lichen is composed of wide, flat, ribbon-like lobes. The upper side of the lobes are a dull, pale brownish-grey, which becomes a deeper brown when wet. The lower side is a dirty white with conspicuous narrow, raised veins and is covered with prominent tooth-like append ges. It is quite common.

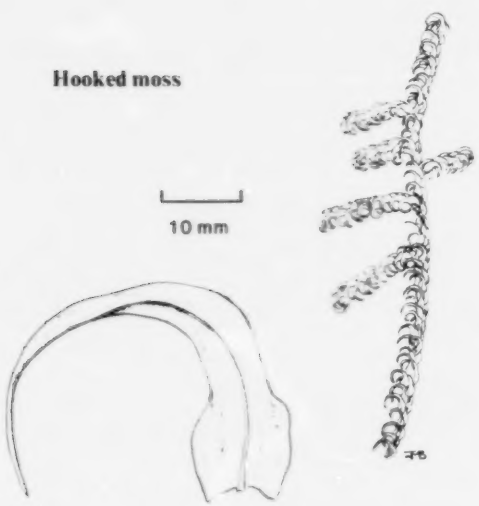


Mosses



Aulacomnium palustre (Hedw.) Schwaegr.

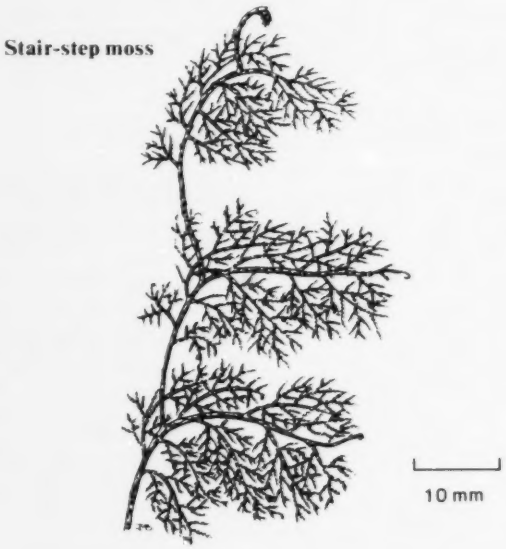
This is a large, conspicuous, vivid light yellowish green moss usually growing upright in tight mats or clumps. The stems are densely matted with rust-colored, wool-like hairs. The leaves are held erect or slightly spreading and are oblong with a slightly rounded point. These leaves are large, especially near the top of the stem. Enlarged orange cells at the corner of the leaf base form patches visible with the naked eye. It is common in wet shaded sites and peaty meadows.



Drepanocladus uncinatus (Hedw.) Warnst.

Hooked moss

This is a golden-green, glossy moss forming in soft, loose tufts or mats. Its stems creep or are more or less erect when crowded. The branches are rather irregular and the leaves gradually taper to a long curved point, slightly pleated, with a single, obvious nerve. All the leaves curve downwards or in one direction giving the moss a quite distinct appearance. However, this moss is very variable, often rather straggling, and causes some trouble in identification. It is common in wet places, but is never submerged.



Hylocomium splendens (Hedw.) BSG

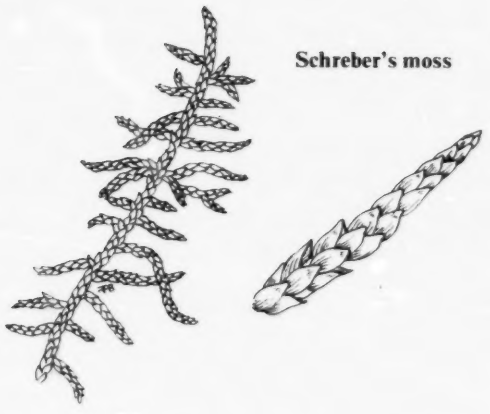
Stair-step moss

This is a yellow, golden or brownish green moss with a silky gloss, and stiff stems which are wiry, reddish brown and covered with green scales. Each year's growth originates from the center of the previous year's growth in successive sprays which give the moss a characteristic step-like form. The branches are branched two or three times giving a lacy effect to the horizontally flattened fronds. The leaves are egg-shaped, pointed, concave and slightly pleated. The nerves are short and double. It is found in relatively rich, moist woods.

Pleurozium schreberi

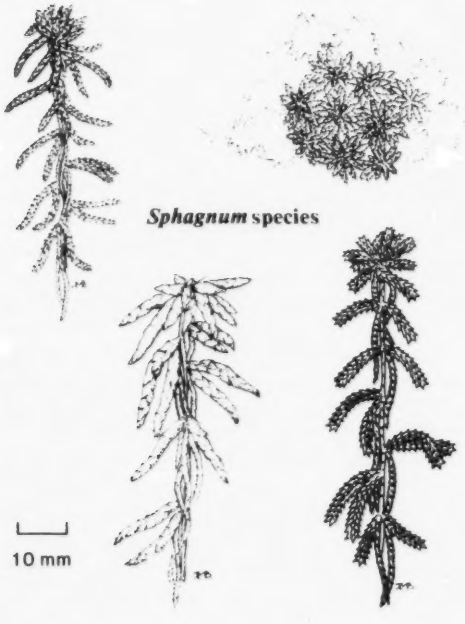
Schreber's moss

This is a large feathermoss characterized by a bright, shiny, almost translucent yellowish green



Schreber's moss

color. It forms thick, extensive mats. The stems are red and visible through the leaves which are semi-transparent, pale green, egg-shaped or oval, and somewhat curved. It is arranged to give the branches a somewhat succulent appearance when wet. The capsule is cylindrical, horizontal, often very curved, on a somewhat glossy red-brown stalk.

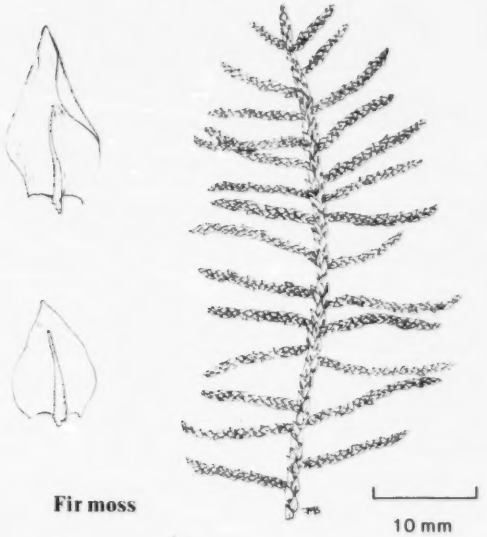


***Sphagnum* species**

Sphagnum species

Sphagnum mosses

These are obvious, robust mosses, usually growing in deep hummocks, tight cushions or extensive mats in wet habitats. The stems are long to very long, extending deep into hummocks. There are many branches which are spreading or drooping and covered in leaves. The branches at the tip of the stems are clustered into more or less compact heads. Colors range from pale or dark green through yellow, brown, crimson or violet. Sphagnum mosses are usually found on wet sites.



Fir moss

Thuidium abietinum (Hedw.) B.S.G.

Fir moss

Fir moss is a rather coarse, dark brown to dark green, wiry moss, unmistakable in the field. Its stems are erect or arching, simply pinnately branched, and resemble branches of *Abies* (Fir). The branches are rather short and unequal. The leaves are egg-shaped narrowing to a bluntly pointed tip, and concave. The nerves are single, short, and stout. It is found on sunny, dry, lime-rich slopes, and in conifer woods.